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ALL ABOUT SPACE

ISSUE 132
AUGUST 2022

SPECIAL REPORT

GIANT LEAP TO MARS' PHOBOS

LAUNCH FOR THE MOON

HOW A BRAND-NEW MISSION WILL LAND ASTRONAUTS ON THE SURFACE BY 2025

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Leslie Kean

WELCOME

ISSUE 132

This August, all being well, Artemis I will be launching for the Moon. The spacecraft is the first in a series that will eventually enable humankind to further explore our natural satellite and Mars on foot. Not only that, but the NASA program aims to be the first to land a woman and a person of colour on another world – a truly astonishing feat that will change the face of manned space exploration. You can keep up to date with the latest news, including the actual launch, by following our social channels and on our sister site **space.com**. We'll be following the action every step of the way.

While we wait for Artemis I to leave the launchpad at Kennedy Space Center aboard the Space Launch System, I hope you're kept entertained by what we have in store for you this issue: this month you can feast your eyes on our top picks of summer deep-sky targets, discover the secrets of dark energy, learn the answers to your burning questions about the cosmos and much more.

Enjoy the issue, and I'll see you next time for another packed one!

GEMMA LAVENDER
Content Director

ALL ABOUT SPACE
ISSUE 133
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11 AUGUST

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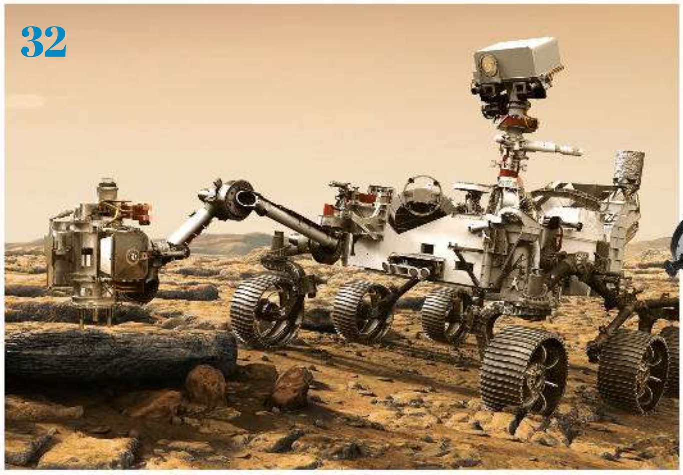

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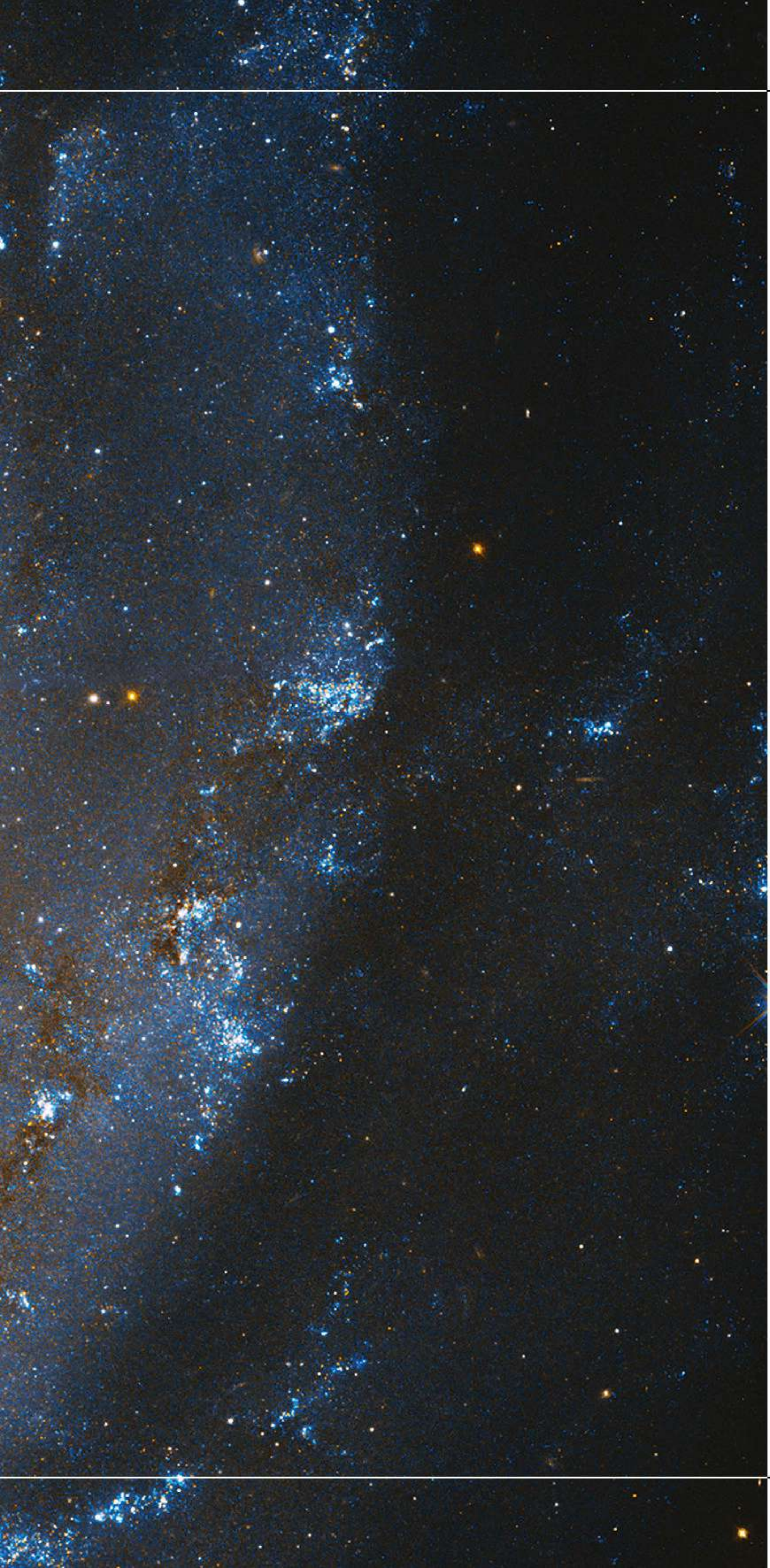


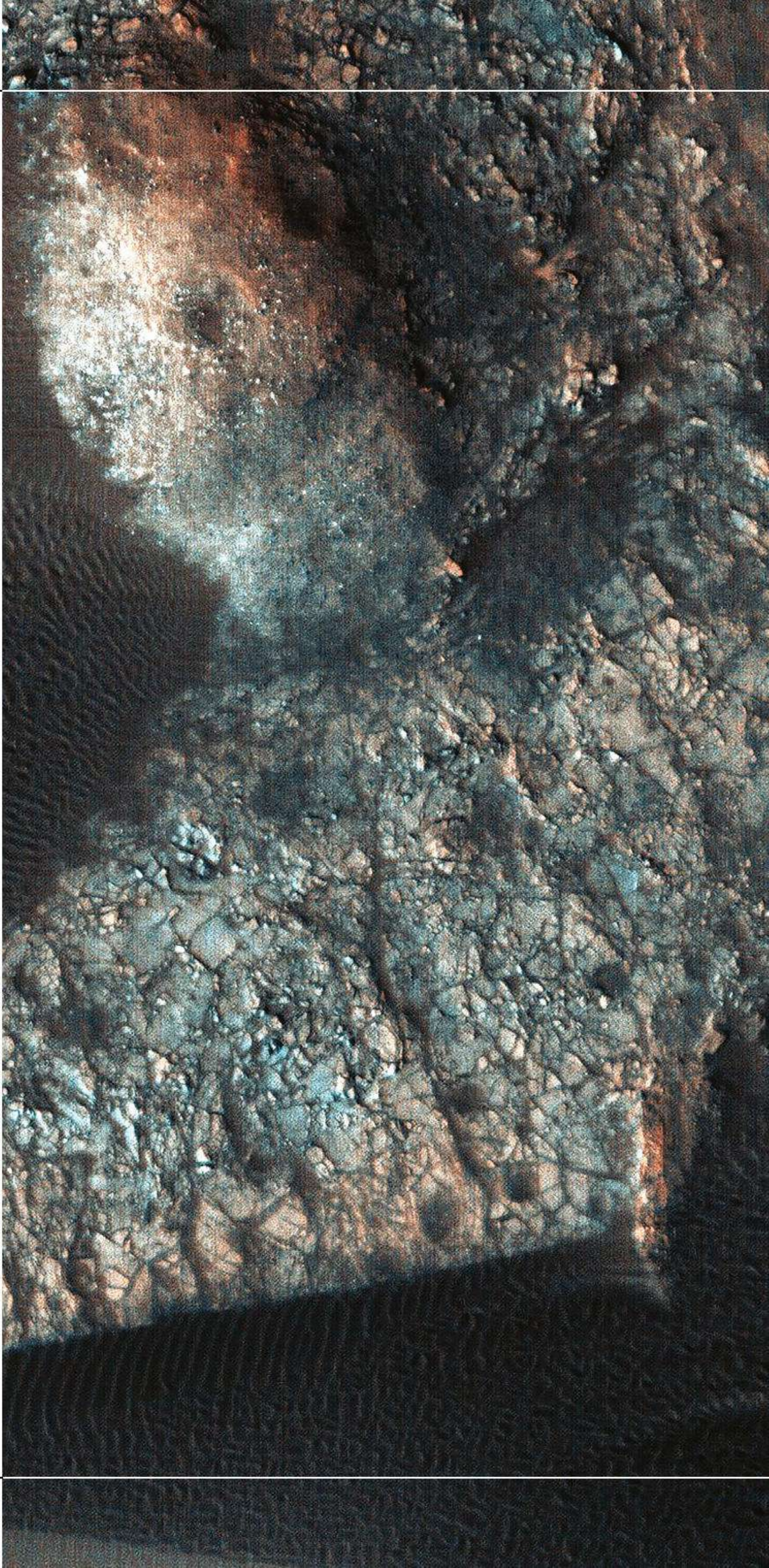
26 May 2022

Hubble's heavenly view

This sky full of stars from the Hubble Space Telescope is a heavenly view. It's a galactic image from the telescope's Wide Field Camera 3 and Advanced Camera for Surveys, focusing on NGC 3631. The spiral arms of the 'Grand Design Spiral', as this object is nicknamed, are absolutely brimming with starbirth. The blue colouring in the image represents visible wavelengths and orange is showcasing infrared or heat-rich areas that are otherwise difficult to see due to dust in the way.

"Star formation in spirals is similar to a traffic jam," NASA said about the new image. "Like cars on the highway, slower moving matter in the spiral's disc creates a bottleneck, concentrating star-forming gas and dust along the inner part of their spiral arms. This traffic jam of matter can get so dense that it gravitationally collapses, creating new stars – here seen in bright blue-white." Situated 53 million light years from Earth, NGC 3631 is found in the constellation of Ursa Major.

© NASA/ESA



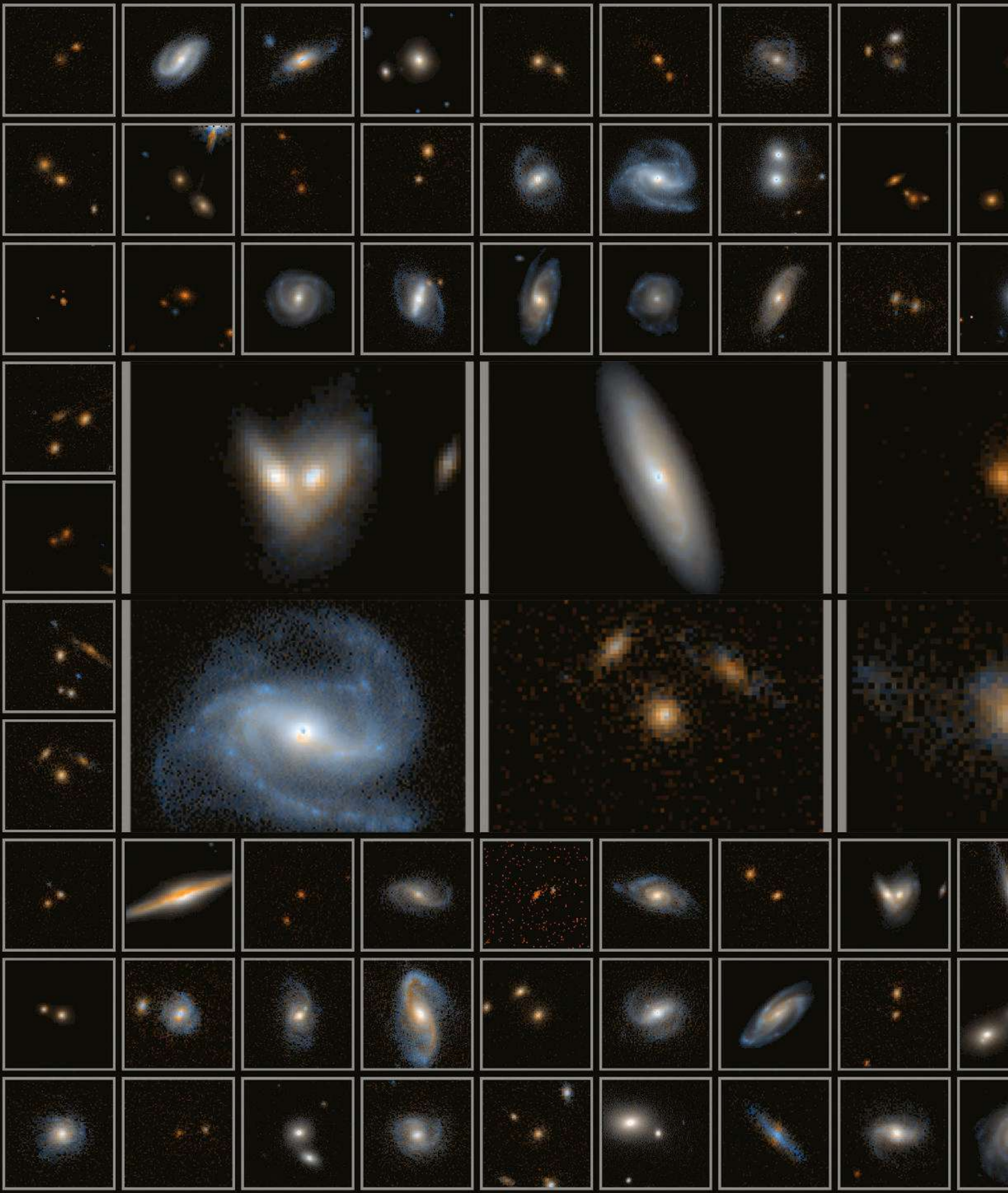
7 June 2022

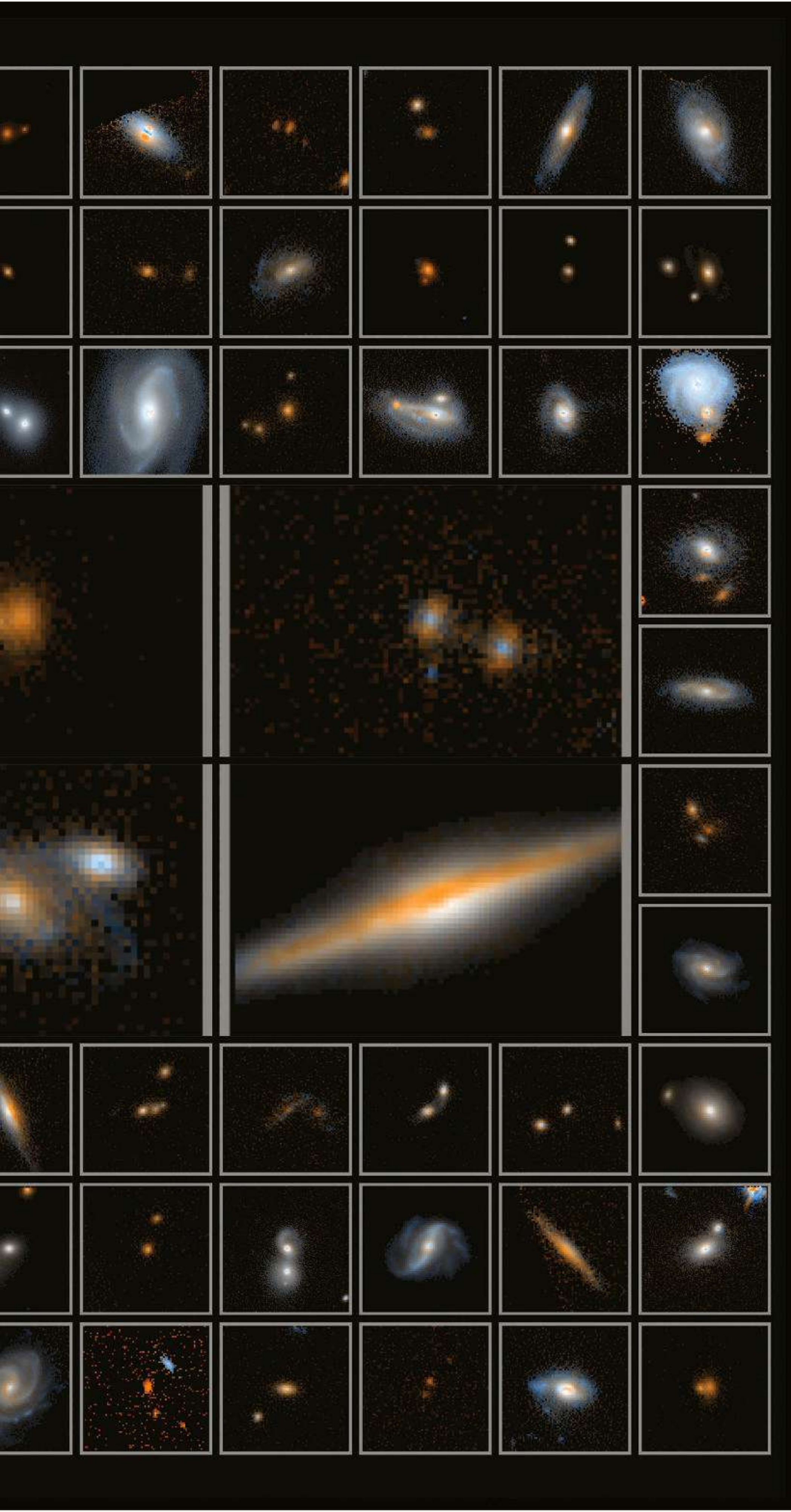
Martian dunes in 3D

Scientists are tracing the movement of dust over Martian aeons using a high-definition camera from orbit. A Twitter account for the Mars Reconnaissance Orbiter's High Resolution Imaging Experiment, at work at Mars since 2006, recently posted a picture of barchan dunes formed by the Red Planet's winds pushing continuously in a single direction. "Who doesn't like an image of dunes in 3D," a tweet said along with the picture. "Pay attention to the sand 'thread' on the right side of the image. Interesting how that might have formed."

While mission experts provided few details with the image, scientists have been probing the Nili Patera region for many years now in an attempt to figure out how the dunes evolve over time. A 2012 study showed remarkably swift movements across 105 days, during which some dunes travelled as much as 4.5 metres (15 feet). Barchan dunes are formed as the wind slowly moves sand grains up the slope of the dunes, creating small ripples on the slope. "When the sand grains arrive at the top, they fall down the steeper and shorter slope, which as a consequence has no ripples," NASA said. "It's this gradual sand movement that causes the dunes to slowly move over time."

© NASA/JPL-Caltech/University of Arizona





Billion-year-old galaxies

The largest near-infrared image of galaxies ever taken by Hubble has provided a playground for astronomers seeking out potential targets for the James Webb Space Telescope. The image spans 1.35 square degrees of the sky – equivalent to about six full Moons – and contains thousands of galaxies. The aim is to identify galaxies worthy of further study by Webb and other telescopes in the future.

"I am curious about giant galaxies, which are the most massive ones in the universe formed by the mergers of other galaxies," said Lamiya Mowla, an astronomer at the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto and leader of the new research. "How did their structures grow, and what drove the changes in their form? It was difficult to study these extremely rare events using existing images, which is what motivated the design of this large survey." Ordinarily, it would have taken Hubble 2,000 hours' worth of observations to build an image this large, but Mowla's team used a new technique called Drift and Shift (DASH) which takes multiple shots and stitches them together.

© MPIA/Lamiya Mowla

Ryugu is a remnant from the formation of Earth and the other planets

Asteroid Ryugu contains material older than the planets

Reported by Mike Wall

Ryugu contains some of the most primitive material ever studied on Earth, dating back to just 5 million years after the formation of the Solar System according to analyses of samples retrieved by Japan's Hayabusa2 mission. Because it's so old, it's made of the same material that formed the planets. "Ryugu is one of the building blocks of Earth," Hisayoshi Yurimoto, a professor at Hokkaido University in Japan, said.

The Japan Aerospace Exploration Agency's Hayabusa2 launched in 2014 and arrived at Ryugu in 2019. It retrieved two small samples of regolith from the asteroid. These samples then landed on Earth in a capsule equipped with a parachute in December 2020. Upon their return, the samples were distributed among scientific groups, including one team led by Tetsuya Yokoyama, a professor at the Tokyo Institute of Technology. The team's newly published results suggest that the composition of the samples is the closest match to the solar nebula – the gas cloud that condensed to form the Sun and planets – ever found, made up of the ingredients that formed the Solar System 4.5 billion years ago. The findings support previous research that also concluded that Ryugu was made of primitive material, but until now it wasn't known just how old it was.

Ryugu is a carbonaceous chondrite, meaning it's made from carbon-rich stony material. Remote observations by Hayabusa2 found some unexplained discrepancies, including a darker surface colour, a larger abundance of phyllosilicate materials and a more porous composition than expected. Laboratory analysis was required to better understand it's true nature. Ryugu is somewhat similar to the Ivuna meteorite which fell in Tanzania in 1938 and was loaned to Yokoyama's team.

Utilising a range of techniques, including electron microscopy, X-ray fluorescence, inductively coupled plasma mass spectrometry and thermal ionisation, the team found that the samples had formed within liquid water at a temperature of about 27 to 47 degrees Celsius (81 to 117 degrees Fahrenheit) roughly 5 million years after the Solar System began to form. With a diameter of 900 metres (3,000 feet), Ryugu is too small to have generated enough heat to melt water ice. Ryugu itself must have originated from a larger parent body that formed just 2 to 4 million years after the birth of the Solar System. At some point after 5 million years, a powerful impact with another asteroid smashed Ryugu's parent body apart, with some of the fragments forming Ryugu. This idea is supported by the presence of large boulders on Ryugu's surface, which appear to have originated as debris from a giant impact.

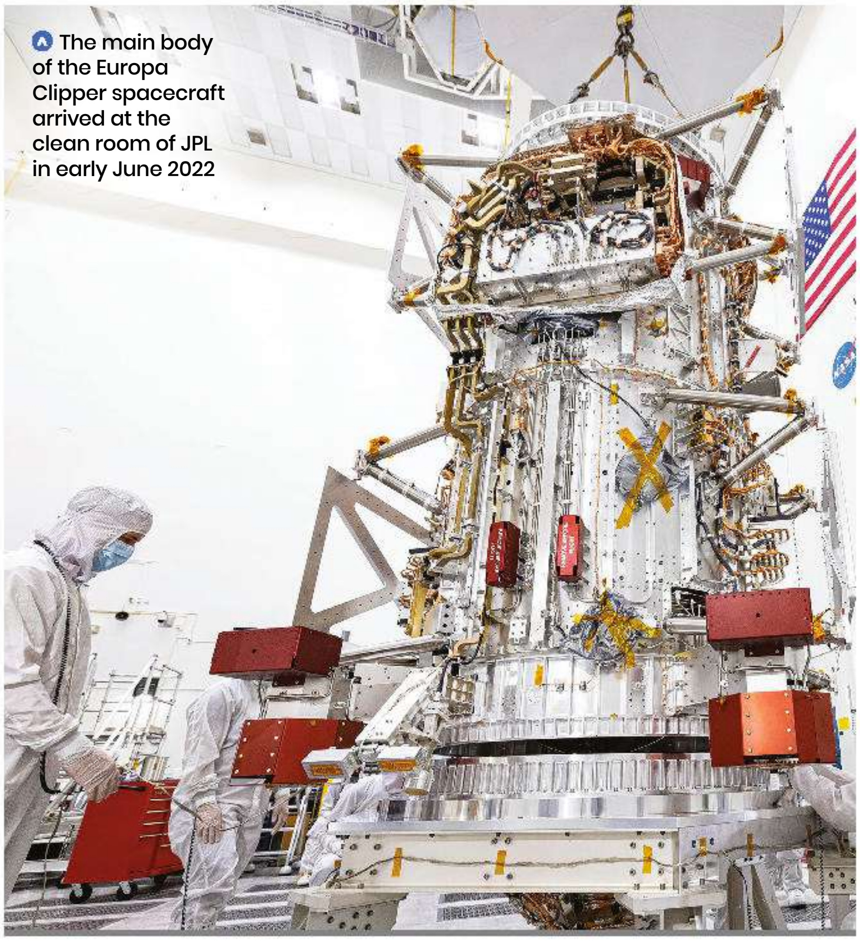
One key question that needs to be answered to fully explain the origin of the planets is where minor bodies such as asteroids and comets, some of which became planetary building blocks, formed. Their compositions suggest that many of these bodies did not form in their current orbits and that in the chaotic early solar system, with its turbulent protoplanetary disc and migrating planets, the minor bodies were pushed around and moved away from where they formed.

NASA's Europa Clipper spacecraft takes a big step towards its 2024 launch

Reported by Andrew Jones

NASA's Europa Clipper mission is one step closer to starting its journey to Jupiter's icy moon. The main body of Europa Clipper is an aluminium cylinder that clocks in at three metres (ten feet) tall and 1.5 metres (five feet) wide. Fitted out with integrated electronics, cabling and a propulsion system, the spacecraft body arrived at NASA's Jet Propulsion Laboratory (JPL) in southern California in early June. "It's an exciting time for the whole project team and a huge milestone," Jordan Evans, the mission's project manager at JPL, said. "This delivery brings us one step closer to launch and the Europa Clipper science investigation."

Engineers and technicians will now work on the assembly of Europa Clipper – including integrating the mission's nine science instruments – to prepare the spacecraft for launch on a SpaceX Falcon Heavy rocket in October 2024. The Europa Clipper, named for the three-masted, ocean-going merchant ships of the 19th century, plans to conduct nearly 50 flybys of Europa, an icy moon of Jupiter that scientists believe has an internal ocean containing twice as much water as Earth's oceans combined. Scheduled to arrive in the Jupiter system in 2030, the spacecraft will use its suite of instruments to gather data about Europa's atmosphere, surface and interior to begin to answer questions about the moon's habitability. Europa Clipper will also scout for potential water plumes venting samples of the theorised subsurface ocean out through Europa's fractured and crisscrossed crust.



The main body of the Europa Clipper spacecraft arrived at the clean room of JPL in early June 2022

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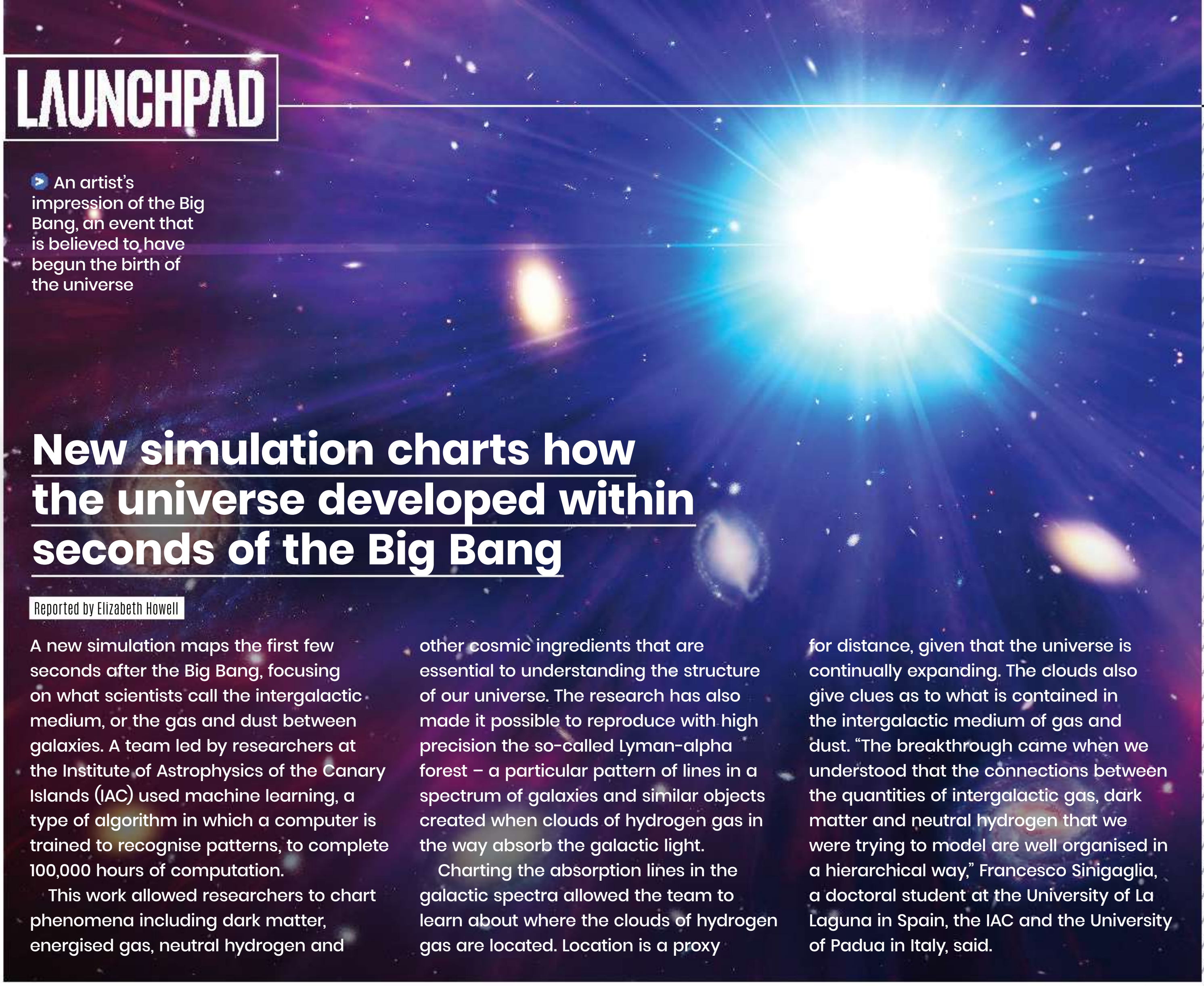

An artist's impression of the Big Bang, an event that is believed to have begun the birth of the universe

New simulation charts how the universe developed within seconds of the Big Bang

Reported by Elizabeth Howell

A new simulation maps the first few seconds after the Big Bang, focusing on what scientists call the intergalactic medium, or the gas and dust between galaxies. A team led by researchers at the Institute of Astrophysics of the Canary Islands (IAC) used machine learning, a type of algorithm in which a computer is trained to recognise patterns, to complete 100,000 hours of computation.

This work allowed researchers to chart phenomena including dark matter, energised gas, neutral hydrogen and other cosmic ingredients that are essential to understanding the structure of our universe. The research has also made it possible to reproduce with high precision the so-called Lyman-alpha forest – a particular pattern of lines in a spectrum of galaxies and similar objects created when clouds of hydrogen gas in the way absorb the galactic light.

Charting the absorption lines in the galactic spectra allowed the team to learn about where the clouds of hydrogen gas are located. Location is a proxy for distance, given that the universe is continually expanding. The clouds also give clues as to what is contained in the intergalactic medium of gas and dust. "The breakthrough came when we understood that the connections between the quantities of intergalactic gas, dark matter and neutral hydrogen that we were trying to model are well organised in a hierarchical way," Francesco Sinigaglia, a doctoral student at the University of La Laguna in Spain, the IAC and the University of Padua in Italy, said.

Dishes of the Jansky Very Large Array

© Getty

Second repeating fast radio burst discovered

Reported by Andrew Jones

An international team of astronomers has discovered a second persistently active fast radio burst (FRB), posing questions about the nature of these mysterious phenomena. FRBs are intense, brief flashes of radio-frequency emissions lasting on the order of milliseconds. The phenomenon was discovered in 2007 by graduate student David Narkevic and his supervisor Duncan Lorimer. The source of these highly energetic events is a mystery, but clues as to their nature are being gradually collected.

The new source, FRB 20190520B, was detected with the Five-hundred-meter Aperture Spherical radio Telescope (FAST) in Guizhou, China, on 20 May 2019 and found in data in November that year. Follow-up observations by the Jansky Very Large Array (VLA) program led by the California Institute of Technology found weaker, constant radio emissions associated with the FRB, also allowing the Subaru telescope in Hawaii to localise the source to be within the fringes of a dwarf galaxy nearly 3 billion light years from Earth. Notably, it's the second repeating FRB to be associated with a persistent radio source (PRS), following the localisation of FRB 121102 in 2012.

"The big surprise for me was realising that the new FRB seems to be such a perfect 'twin' to an earlier discovery," Casey Law, an astronomer at the California Institute of Technology, said. "Perhaps some would have preferred to say that the first such association was a coincidence, because it was hard to explain. Now the second example shows that this is a real and critical part of the life of an FRB."

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Courtesy of Celestron, you can kick-start your stargazing hobby with this month's competition

Celestron has reinvented the Dobsonian telescope with its StarSense Explorer – the first Dobsonian that uses your smartphone to analyse the night sky and calculate its position in real time. This large-aperture Celestron StarSense Explorer is ideal for serious beginners thanks to the companion app's user-friendly interface and detailed tutorials. It's like having your own personal tour guide of the night sky. The large aperture will ensure that you won't outgrow the telescope as you continue your astronomical adventures.

With a large eight-inch Newtonian reflector optical tube, this telescope has enough light-gathering ability to bring out impressive detail in celestial objects while remaining remarkably portable. You can expect sharp, bright views of the Moon; Jupiter's four Galilean moons, its cloud bands and Great Red Spot; the rings of Saturn; the gaseous glow of the Orion Nebula; dust lanes in the Lagoon Nebula and our neighbouring galaxy, Andromeda.

To be in with a chance of winning, answer this question:

What's the term for a planet that orbits a star beyond our Solar System?

A: Brown dwarf

B: Extrasolar planet

C: Pulsar

Competition ends on 11 August 2022

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LAUNCH FOR THE MOON

NASA's biggest mission in over 50 years will put boots back on the Moon and bring us one step closer to Mars

Reported by Ailsa Harvey

The Moon has captured the attention of humankind for as long as we have gazed upon the stars. Reflecting the Sun's light each dark night, its presence reminds us of worlds beyond our own. But astronauts have done much more than simply look upon it. On 20 July 1969 the first humans landed on the Moon. As part of a series of missions dubbed the Apollo program, NASA astronauts returned to Earth with more knowledge of the rocky orb than our species had ever acquired before. But to think that a handful of missions to this world would make us experts of this foreign terrain would be a mistake. We have only explored a tiny portion of the Moon, and there is still so much more to learn.

It's been half a century since we last visited the Moon, and NASA has made clear its plans to place the next astronauts on its surface by 2025. At least two more people will follow in the few dusty footsteps of the Apollo program's moonwalkers. When the Apollo program was launched, we knew few details about the silvery sphere that graces our skies. Upon the astronauts' successful return to Earth with samples from the Moon, we were able to learn the majority of what we know today about our planet's natural satellite. We learned that the surface of the Moon has a dust covering and the structure contains a core, mantle and crust just like Earth's. For Apollo, putting humans on the Moon was the main and final goal. It provided us with a better understanding of what was previously an uncharted and unimaginable environment. Soon this territory is to be further explored, and humanity's achievements in space travel will be expanded upon.

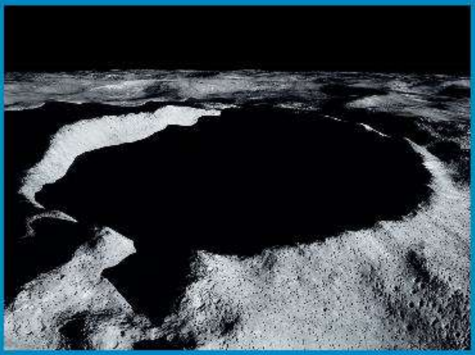
Apollo's successor is Artemis – a program aptly named after the Greek goddess of the Moon. Artemis is also the twin sister of Apollo. While the Apollo missions were executed solely by men, one prime goal of Artemis is to send the first woman to the Moon. In keeping with the theme, the vehicle that will carry the next astronauts to the Moon is a capsule called Orion, the name of the goddess Artemis' hunting partner. Sending a female astronaut to the farthest place humans have been from Earth will be an important step for the global space industry, and for equality.

Perhaps the most ambitious of the Artemis mission's objectives involves using the Moon

> "We have only explored a tiny portion of the Moon, and there is still so much more to learn"

WHERE ARE WE GOING?

For the initial Artemis Moon missions, the selected astronauts will likely fly to the Moon's south pole. This area has great potential as it is believed to be home to the highest abundance of water ice. If we can extract this water, it could be used to sustain human exploration farther into space, whether that's as a human hydration source, rocket fuel resource or cooling system for equipment. Shackleton crater is a huge 19-kilometre (12-mile) depression in the Moon's surface and a feature well worth visiting. With a permanent shadow cast in the dips of the crater, the low temperatures make it a promising location for ice to form. In fact, these permanently lightless areas maintain some of the coldest temperatures in the entire Solar System. Although it's possible that water can be found even on the Moon's lit surfaces, an area likely to have the highest abundance of water is the best spot to start looking for further natural resources.



Shackleton crater is situated almost exactly at the Moon's south pole

© NASA; ESA; Getty; Alamy

THREE-PART PLAN

2022
Artemis I

The first mission will be uncrewed to test the safety of takeoff, the capsule's ability to orbit, descent and splashdown. The rocket will carry 13 small satellites into space to perform experiments and technology demonstrations. For six days the craft will orbit the Moon, collecting performance data.

2024
Artemis II

Carrying the first four Artemis astronauts, the Orion capsule will take the crew farther from Earth than humans have ever travelled before. Over the approximately ten-day mission, the crew will complete a lunar flyby and return to Earth, evaluating the spacecraft's systems while carrying humans.

2025
Artemis III

This will see the next man and first woman step onto the lunar surface. Providing previous missions have been successful, the astronauts will shoot towards the Moon, using the lunar lander to lower two people to the Moon's south polar region. They will remain on the Moon for around a week.

> "The Moon is a stepping stone – in both time and distance – towards the Martian dream"

as a stepping stone for a mission to Mars. This is a planet that scientists believe could have once been home to life. Robots have done all the detective work on Mars so far, but NASA now aims to send astronauts there by the 2030s. With a future target set on the Red Planet, the return to the Moon will be used to provide us with the knowledge and tools to better navigate our Solar System.

But how can the Moon help prepare us for a mission to Mars, an entirely different and more unpredictable mission? Part of this logic is to maintain a gradual progression towards Mars, ensuring that astronauts are as experienced as they can be.

Mission Control Center
EECOM

Humans have evolved to thrive on Earth, and they can't survive by themselves outside its atmosphere. In order to cheat nature and explore space, astronauts rely on science and technology, with NASA planning and preparing extensively. Much of what we know about how the human body reacts to low gravity, the hostility of outer space and how humans can survive in space comes from ongoing experiments on the International Space Station (ISS). Living 400 kilometres (248 miles) above our planet's surface is unimaginable to most of us, but a two-day journey to the ISS from Earth is nothing compared to the months it would take to travel to Mars. The Moon is a stepping stone – in both time and distance – towards the Martian dream.

The Artemis plans are well underway, and the first three missions are likely to be the catalyst for many more. Although NASA's sharpest minds will have the trip meticulously calculated, exactly what the astronauts will find remains to be seen. As the mission draws closer, a recent discovery has added significance to this ambitious plan. NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) discovered that the Moon has a higher abundance of water than previously anticipated and across a much greater area. The water was found on a sunlit surface of the Moon, meaning any available water isn't limited to the coldest, darkest regions and deep craters, as previously suggested. There could be more of this life-supporting resource trapped within the lunar surface for Artemis explorers to utilise. If this vital resource can be spotted using distant telescopes, time will only tell what we will learn when the Moon is back beneath our feet.

Ailsa Harvey
***How It Works* staff writer**
Ailsa writes for **How It Works** magazine, where she investigates topics in science, technology, history, space and the environment.

▲ Astronauts will perform experiments and collect samples for return to Earth

► Spacesuits have seen massive upgrades since the Apollo era

◄ The Artemis I Flight Control Team simulating mission scenarios at Johnson Space Center

© NASA; Getty

MAIN MISSION OBJECTIVES

Long-term presence

Following Apollo 17's three-day presence on the Moon, Artemis will send astronauts there for weeks.

Equality

A female astronaut hasn't set foot on the Moon yet. This mission will demonstrate the increasing role women have played in space missions since the Apollo era.

Partnerships

NASA has collaborated with private companies such as SpaceX and Boeing. These show space travel's shift towards commercialisation.

Technology

NASA is always learning from past missions; the spacecraft and spacesuits have been tailored to the Moon mission, exhibiting the latest in space technology.

Knowledge

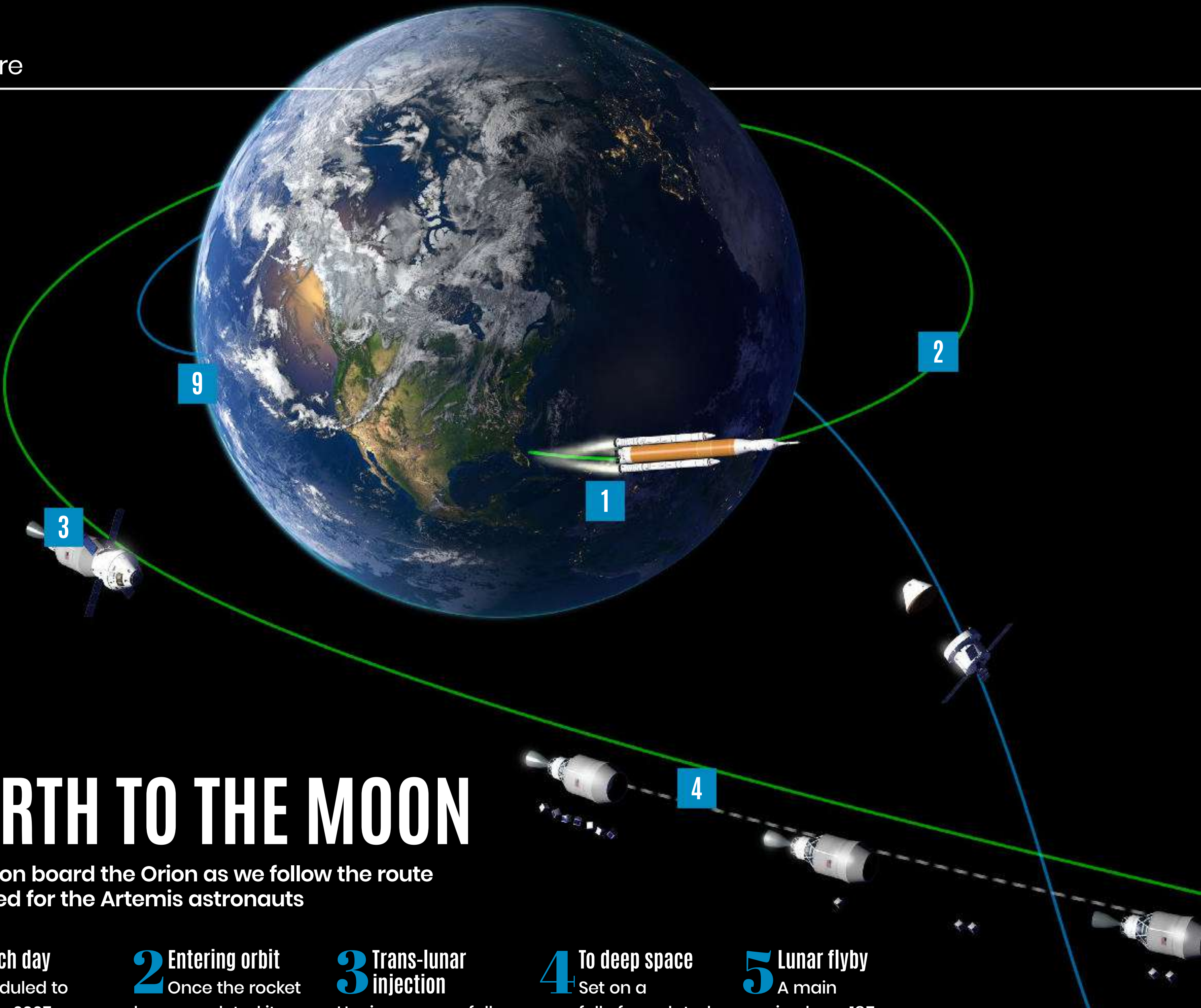
Collecting further information about the lunar surface and deep space, NASA hopes to become better prepared for later missions back to the Moon and further afield.

Resources

Access to the lunar surface provides the opportunity to search for rare mineral deposits and exploit resources. Hydrogen and oxygen could be used as rocket fuel to travel from the Moon.

MOONWALKERS

If we want to send astronauts to the Moon, they will need the latest technology to assist them. While astronauts have undergone multiple spacewalks since the Apollo missions, these have not required them to walk on the surface of a celestial body. The next astronaut to walk on the Moon will do so in a brand-new, updated spacesuit. NASA has unveiled Artemis-generation spacesuits designed especially for the mission: one for the launch and landing, worn inside the spacecraft, and one to protect the bodies of those venturing outside the protection of the Orion capsule. The suits will be custom fit to their bodies, with the aim of improving upon the comfort and practicality of previous versions.



EARTH TO THE MOON

Jump on board the Orion as we follow the route planned for the Artemis astronauts

1 Launch day

Scheduled to launch in 2025, the third Artemis mission and second with crew on board launch from the Kennedy Space Center in Florida. All the action will be watched and monitored by the nearby Launch Control Center.

2 Entering orbit

Once the rocket has completed its task of taking Orion into orbit, its engines shut down and it will separate from the capsule. These rocket components then fall towards the Pacific Ocean. Left to fend for itself, Orion will deploy its solar arrays.

3 Trans-lunar injection

Having successfully made it into Earth orbit, the Orion vehicle is ready to cross over to the Moon. During a 20-minute burn, the engines fire to increase the speed of travel, displacing the spacecraft from its low-Earth orbit.

4 To deep space

Set on a carefully formulated trajectory, Orion will travel over 384,000 kilometres (239 miles). This needs to account for factors such as the pull of gravity and the movement of the Moon. Artemis I will be able to test the planned path.

5 Lunar flyby

A main engine burn 185 kilometres (115 miles) above the Moon's surface will put Orion on a trajectory to intercept the orbit of the planned Lunar Gateway space station, set to launch in November 2024.

6 Moon landing

Having docked with Gateway, the crew may need to inspect the station and collect any supplies they might need. While two astronauts will stay aboard the spacecraft in orbit, the other two will change over into a lander vehicle.

7 Spacewalk

The astronauts are likely to explore Shackleton crater, and will remain on the Moon for roughly seven days. As an area where water ice is present, they will explore the suitability of the lunar south pole for a permanent Moon base.

8 Ascent

Having carried out experiments on the Moon, the astronauts will reboard the Human Landing System and return to Gateway. Taking any essential samples back to Earth with them, they will return to Orion to make the journey back home.

9 Splashdown

After less than 30 days in space, the parachuted capsule will land on Earth, its fall cushioned by the Pacific Ocean. NASA will have a team ready to retrieve the crew and the capsule.

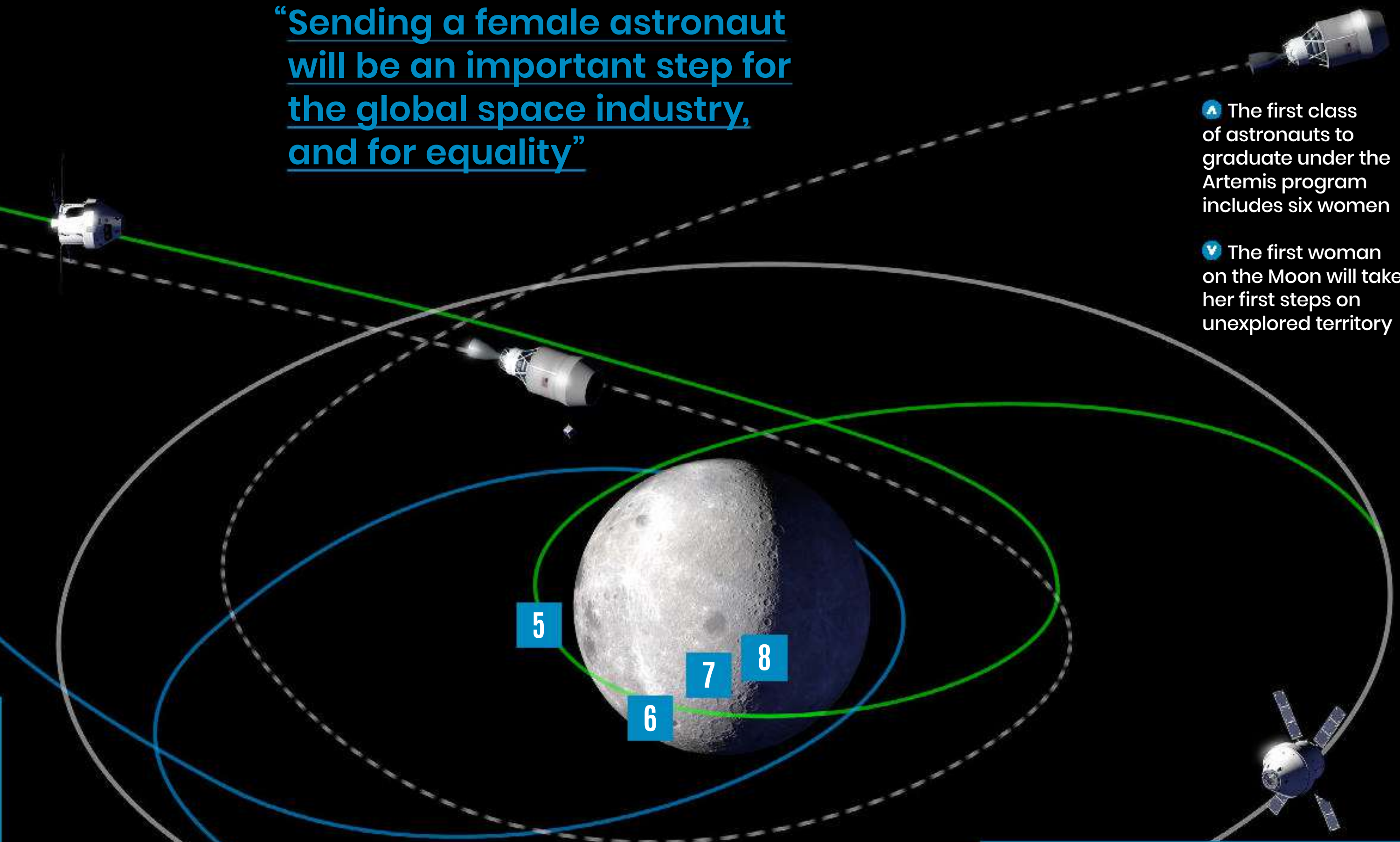
FIRST WOMAN

Between 1969 and 1972, six missions took place in which 12 people walked on the surface of the Moon – all of them men. For such a high-risk mission, the most experienced astronauts were required, and at the time there were no women at NASA who had suitable test flight experience. For a long time space was viewed as an industry primarily for men, and it wasn't until 1978 that NASA selected its first female astronauts. As of March 2022, 75 women have been to space, and this mission will serve as a reminder of changing times.

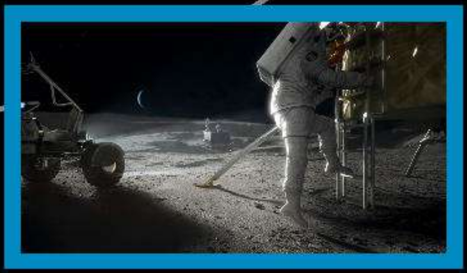
While it's currently undecided who will be chosen, it will be one of NASA's astronauts who has already worked aboard the International Space Station. The team of astronauts is expected to be announced at least two years prior to the mission launch.

The first class of astronauts to graduate under the Artemis program includes six women

> "Sending a female astronaut will be an important step for the global space industry, and for equality"



The first woman on the Moon will take her first steps on unexplored territory



NASA testing exit procedures from an Orion spacecraft

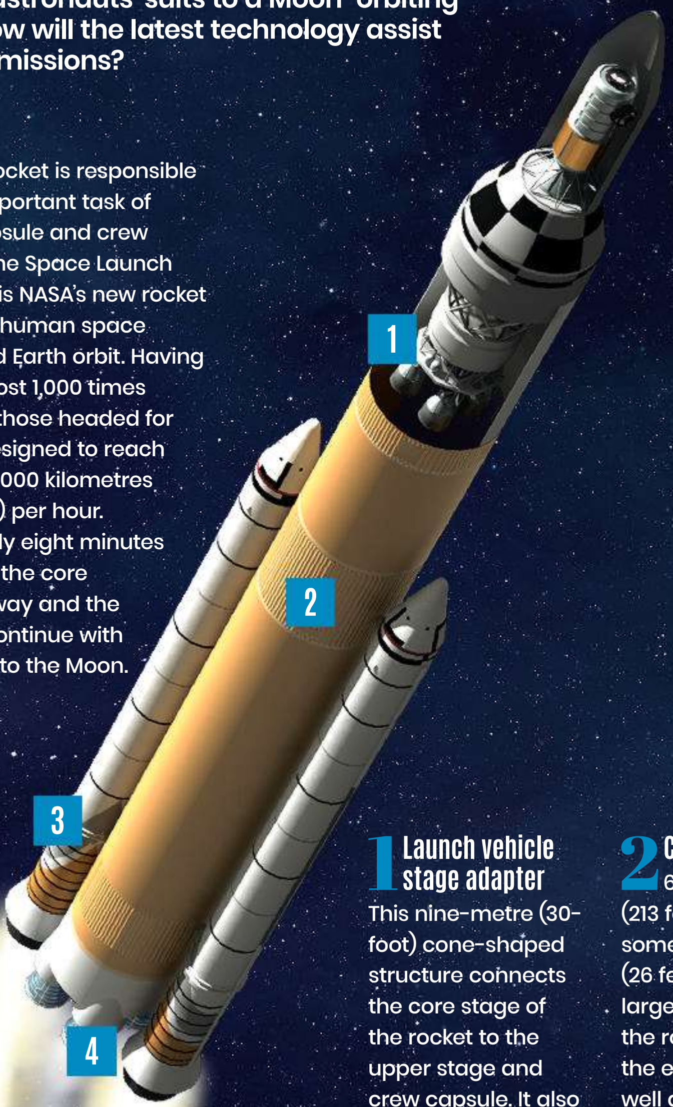
© NASA

TECH CHECK

From the astronauts' suits to a Moon-orbiting station, how will the latest technology assist the Moon missions?

Launch

The launch rocket is responsible for the all-important task of firing the capsule and crew into space. The Space Launch System (SLS) is NASA's new rocket designed for human space travel beyond Earth orbit. Having to travel almost 1,000 times farther than those headed for the ISS, it's designed to reach speeds of 40,000 kilometres (25,000 miles) per hour. Approximately eight minutes after launch, the core stage falls away and the astronauts continue with their journey to the Moon.



TRAVEL TECHNOLOGY

The Orion spacecraft that will deliver astronauts to the Moon is designed to have the lowest mass possible while still being strong enough to withstand the conditions of space. This will enable the capsule to carry the astronauts and their equipment using minimal fuel.

1 Launch vehicle stage adapter

This nine-metre (30-foot) cone-shaped structure connects the core stage of the rocket to the upper stage and crew capsule. It also acts as a protective shield for the engine in the upper stage.

2 Core stage

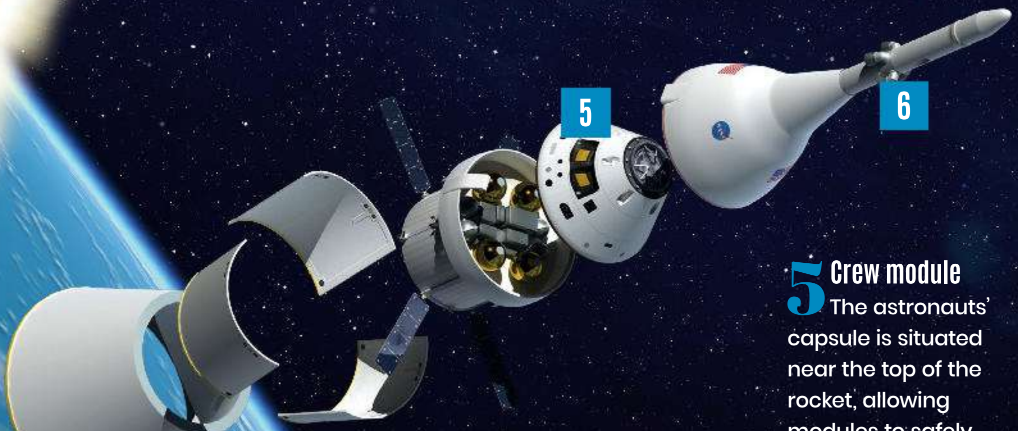
65 metres (213 feet) tall and some eight metres (26 feet) wide, the largest area of the rocket stores the engine fuel as well as the flight computers needed to control the rocket.

3 Solid rocket booster

These provide 75 per cent of the rocket's thrust during launch. After the initial ascent, the boosters separate from the SLS and fall back to Earth.

4 RS-25 engines

Liquid hydrogen and liquid oxygen-fuelled engines are evenly distributed in a square pattern to add stability, as they produce nearly 9 million newtons of force. It takes five seconds for the engines to reach 100 per cent power.

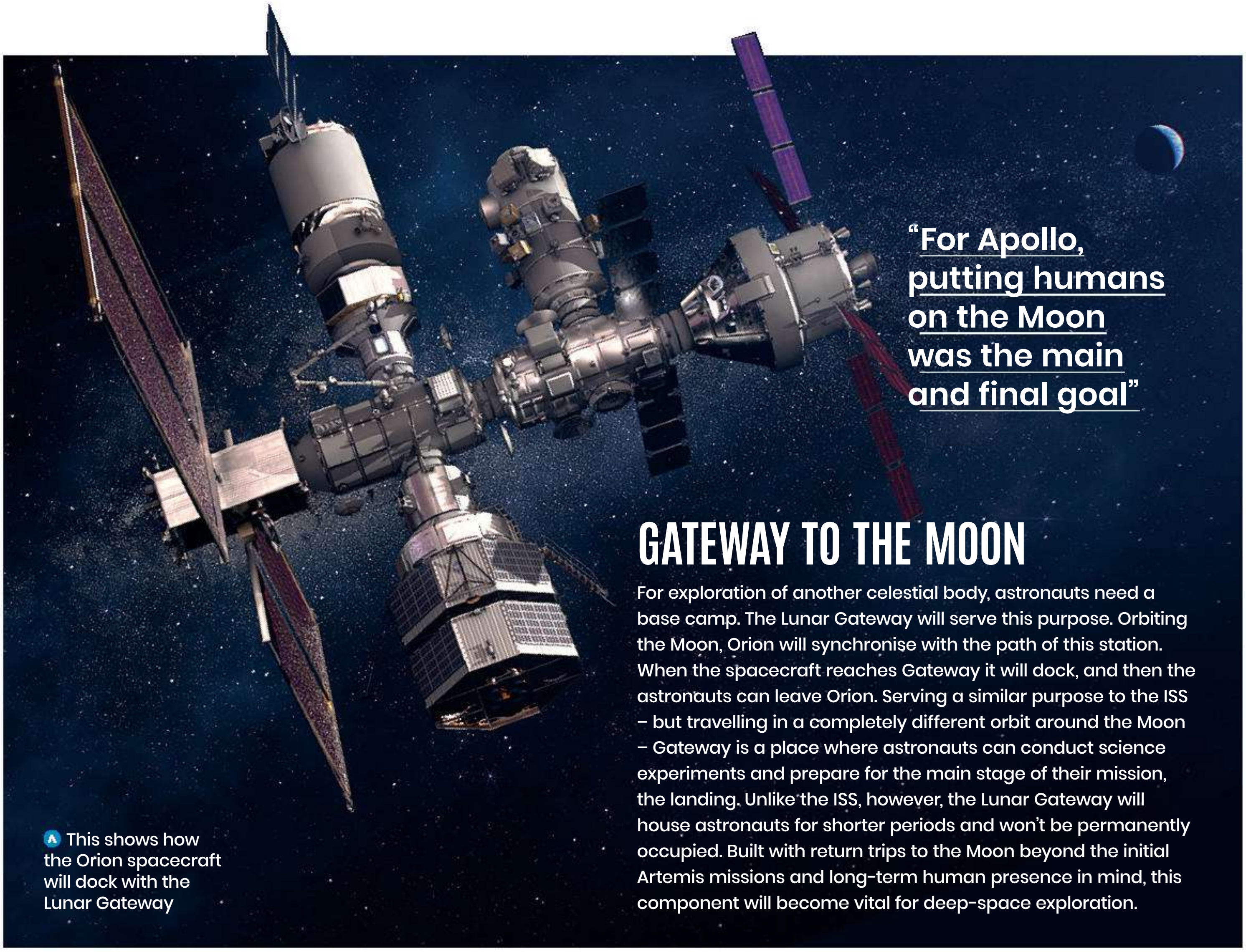


5 Crew module

The astronauts' capsule is situated near the top of the rocket, allowing modules to safely detach below them.

6 Launch abort system

Coming into play if a problem arises, the top of the rocket has a motor that will pull the Orion spacecraft away from the rest of the rocket for a safe landing.



> “For Apollo, putting humans on the Moon was the main and final goal”

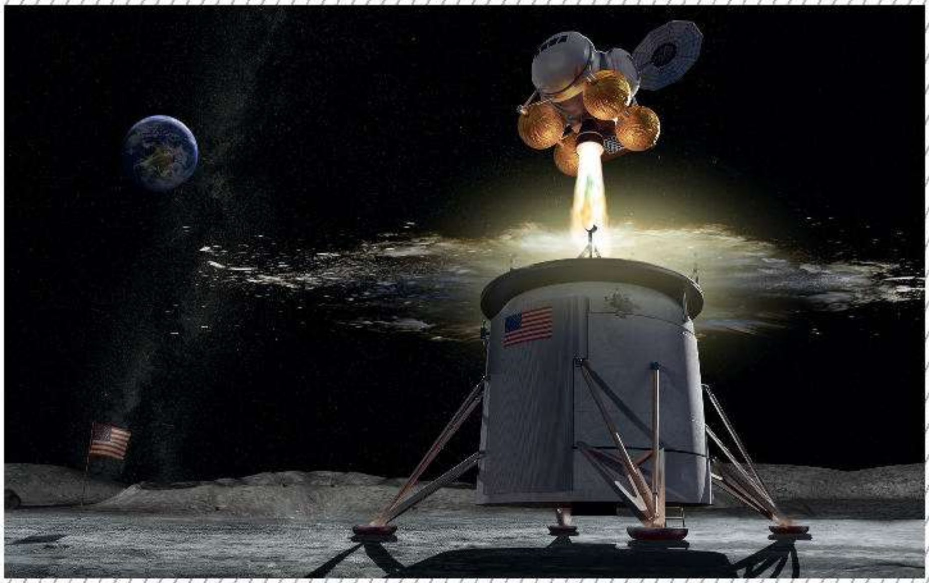
GATEWAY TO THE MOON

For exploration of another celestial body, astronauts need a base camp. The Lunar Gateway will serve this purpose. Orbiting the Moon, Orion will synchronise with the path of this station. When the spacecraft reaches Gateway it will dock, and then the astronauts can leave Orion. Serving a similar purpose to the ISS – but travelling in a completely different orbit around the Moon – Gateway is a place where astronauts can conduct science experiments and prepare for the main stage of their mission, the landing. Unlike the ISS, however, the Lunar Gateway will house astronauts for shorter periods and won't be permanently occupied. Built with return trips to the Moon beyond the initial Artemis missions and long-term human presence in mind, this component will become vital for deep-space exploration.

This shows how the Orion spacecraft will dock with the Lunar Gateway

MOON LANDING

Transporting the astronauts to their lunar destination is the SpaceX Starship Human Landing System. This vehicle is designed with a pressurised crew cabin for its passengers to dwell inside before stepping out onto the surface of the Moon. Other companies working on lunar landers include Blue Origin, Boeing and Dynetics. To safely make it onto the lunar surface, the vehicle will need to achieve a slow soft landing.



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Q&A

STEVEN SWANSON

The three-time NASA astronaut tells us about life in space and the significance of Artemis

Swanson was selected as a NASA astronaut in 1998

During his career at NASA, Swanson logged over 195 days in space, undertaking five spacewalks. His three missions to the ISS include two Space Shuttle flights (STS-117 and STS-119) and one Soyuz flight (TMA-12M).

How does NASA select astronauts?
Nobody knows for sure. Really it's up to the chief of the astronaut office to make that selection, and sometimes others depending on how high profile the mission is. But it's partly just where you are in the queue, because we come in as a group together. The people who came in the group before will fly before you do. I didn't think about an astronaut career until I was about 25. It took 12 years from that point to become one, and I ended up working 11 of those years at NASA as an engineer.

What's it like to spend significant time away from Earth?
I spent about six months in space, and it's not tremendously difficult. Family and friends is the first thing you miss, but we could Skype and the communication with our families was good. You can get down periods when you get a little tired of it – you haven't really gone outside and the food gets old after a while.

How much have the spacesuits improved for Artemis?
The biggest difference is in the shoulders. You get the ability to really reach around and have more movement, like you would without a suit on. They also have better mobility on the legs. On the International Space Station you didn't really use your legs much for anything, so it didn't matter how much mobility you had in your lower body. Now it's going to matter tremendously on the Moon, so they've modified the lower part to be more moveable.

Swanson (left) prepares for the Soyuz TMA-12M launch with Aleksandr Skvortsov (middle) and Oleg Artemyev (right)

© NASA

What changes can the Artemis crew expect in their bodies?
The first thing we have to worry about is muscle and bone loss. Astronauts now work out two hours a day, so we do a pretty good job of mitigating that, but we still see some muscle loss. Bone loss is pretty much covered now. I only had one per cent bone loss from six months on board, and that was a good number. That comes back after about a year.

In our experiments while we were up there, we found that 30 to 40 per cent of the astronauts are getting major changes in their vision, and we haven't figured out exactly why. That's an ongoing process right now. There's just many things that change while you're up there. We've known for a while that the immune system gets degraded, so we're very careful about being quarantined before we go so nobody takes any germs or bugs with them on the way up. You don't want to get sick up there.

How significant do you think the Artemis program is?
The real goal is Mars. And we will use the Moon as a testbed because Mars is a very difficult mission. It's going to take almost three years, and you can't come home early on a Mars mission. It's a seven or eight-month journey to get there and you have to wait 15 months there for the planets to align correctly again before you return. It has to be very well thought out, and the best way to do that is on the Moon. As well as Mars, we can also use the Moon as a testbed for other things – to see how we can actually gather materials from the Moon itself and maybe use that to make our fuel.

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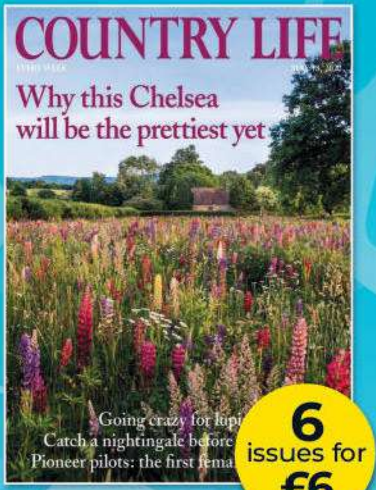
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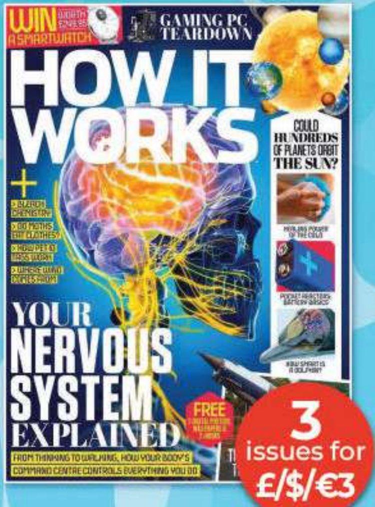
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FUTURE TECH

PROJECT ICARUS

Masterminded in 2009, this mission aims to make the dream of interstellar exploration a reality

By any standard, Project Icarus is a very ambitious attempt at assessing the requirements for an unmanned interstellar probe using current and developing technology. In the process of producing technical reports on the physics, functionality, engineering and performance requirements of the spacecraft needed for different types of mission profiles, it's hoped to provide inspiration for a new generation of scientists and boost the possibility of bringing such a scheme into reality. The project is an update of the British Interplanetary Society's Project Daedalus, which ran from 1973 to 1978. Daedalus envisaged a huge two-stage, 54-million-kilogram nuclear-fusion-powered spacecraft fuelled by deuterium and helium-3.

The intentions of Project Icarus are to design a similar unmanned fusion-powered space probe that can be targeted at a variety of nearby star systems and can reach and scientifically study them within a span of 100 years. The goal is to initiate the launch of such a vehicle by 2100 at the least. The vast scale of this project is underlined by the fact that the helium-3 fuel to power the Daedalus craft can only be gathered in the atmosphere of Jupiter. It would take 20 years for robot factories, held afloat by huge balloons, to mine and process the fuel into coin-sized pellets.

The spacecraft would be constructed in Earth orbit or near Jupiter and propelled by a fusion pulse propulsion engine. 250 fuel pellets per second would be injected into the engine's reaction chamber and detonated by electron beams. To provide the forward thrust, magnetic field coils would channel the plasma produced out of a nozzle.

A variety of smaller craft based on the Daedalus proposal are being considered by Project Icarus, including the Starfinder Mark I that could travel the 10,000 astronomical unit (AU) distance to the Oort Cloud in 50 years and could be launched in 2050. 20 years later, the Starfinder Mark II could visit a star system 50,000 AU away in a period of 100 years. It would take until 2200 to launch anything as ambitious as the original Daedalus spacecraft.

With the increasing amount of extrasolar planets being discovered, it's an exciting possibility that Icarus-inspired spacecraft could explore worlds much like our own by the end of the century.

1 Erosion shield A lightweight beryllium shield protects the 63,500-kilogram spacecraft from the impact of dust particles.

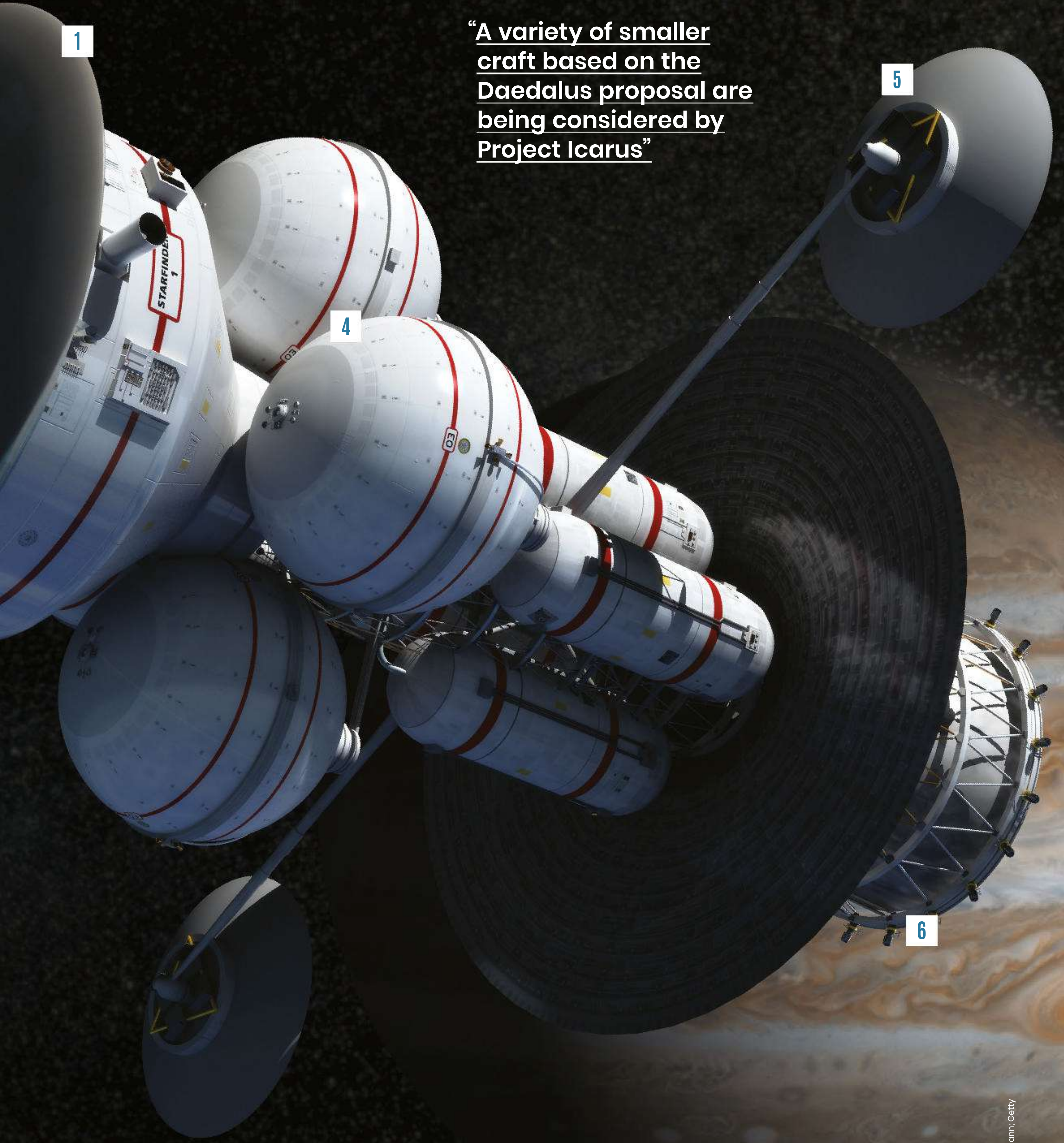
2 Dustbug spacecraft As it approaches its target, small 'Dustbug' spacecraft could seed clouds of particles 200 kilometres (124 miles) ahead of the craft to intercept any large debris.

3 Payload Contains the supercomputer that controls all the spacecraft's systems throughout the journey. The decks in this area contain unmanned probes that will be sent out to explore deep space.

4 Four propellant tanks These fuel the reaction chamber. Once the fuel is expended, these tanks can be individually jettisoned.

5 Antennae These keep the probe in contact with Mission Control on Earth. All data gathered is relayed back to Earth for analysis.

6 Reaction chamber The chamber is made out of very strong yet light titanium-zirconium-molybdenum alloy that can withstand temperatures of 1,327 degrees Celsius (2,420 degrees Fahrenheit).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"A variety of smaller craft based on the Daedalus proposal are being considered by Project Icarus"

© Adrian Mann; Getty

BIO+

Chris Carberry

Carberry is CEO and cofounder of Explore Mars Inc, a nonprofit organisation which was created to advance the goal of sending humans to Mars within the next two decades. Previously, Carberry served as executive director of The Mars Society. He is also the author of science-fiction novel *Celestial Pursuits: In the Hub of the Universe.*

© Getty; Chris Carberry

Chris Carberry

“We’ve never landed something like this on Mars”

All About Space catches up with Chris Carberry, cofounder of Explore Mars Inc, about plans to land humans on Mars’ moon Phobos

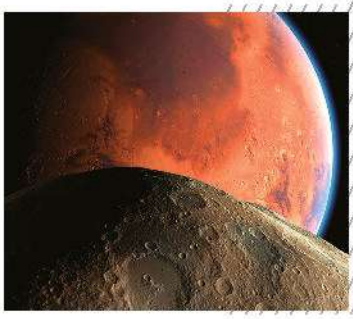
Interviewed by Jonathan O’Callaghan

Why would you choose to go to Mars’ moon Phobos rather than directly to Mars?
This plan is just a concept. It is US policy right now to go to Mars and to the surface of Mars at some point in the 2030s. However, the Jet Propulsion Laboratory (JPL) came out with a plan in which they decided that it might be useful to have a manned precursor mission to Mars orbit first, and in particular go to Phobos and test out key technologies before using it as a stepping stone to Mars.

What key technologies still need testing?
When mission designers talk about the biggest problems in getting to Mars, the two items that keep cropping up are usually life-support technology to keep the astronauts alive and entry, descent and landing (EDL). In other words, keeping the astronauts breathing and making sure they don’t crash! They figure that by going to Phobos first they can reduce the risk by testing out some of the key elements, particularly the life-support systems.

What is complicated about landing craft on Mars?
To appreciate the scale of the challenge, the largest weight we have landed on Mars was the Curiosity rover back in 2012, and then Perseverance in 2020, which I believe was around one tonne. But when we send astronauts to Mars we would need to land at least 30 or 40 tonnes. We wouldn’t be able to lower them with a ‘sky crane’ like we did with the Curiosity rover, and we certainly aren’t landing people with air bags like the rovers had for bouncing into a landing. We’re going to have to find a way to land them softly with retrograde rockets, parachutes or some combination of them both.

We’ve never done anything close to landing something like


Phobos is the larger Martian moon; its orbits the planet in just eight hours

that on Mars, so that's the real challenge. What makes it particularly difficult is the atmosphere. If you ask any Mars scientist, they will tell you that Mars doesn't have enough atmosphere to be of any use in slowing a spacecraft down, but it's just enough that you can't ignore it either. It creates challenges and doesn't slow you down much either, so it doesn't have the benefits that the thick atmosphere of Earth has.

Going to Phobos and then Mars sounds expensive. Is it feasible?

JPL designed the Phobos precursor mission under the assumption that NASA wouldn't get any major increases in budget – just increases for inflation. Under this assumption, the aim is to get to Mars orbit by 2033 and land on the surface of Mars by the late 2030s or early 2040s. However, at Explore Mars we advocate speeding that process up a bit, and we don't think we have to assume it will be a flat budget with just inflationary increases.

We plan for certain increases in NASA's budget over a period of time – and not even permanent increases, just spikes in the budget which might be able to speed it up so that we would be able to land on the surface of Mars by the mid-2030s. The spikes in the budget would be built into the process and scheduled to accelerate the building of certain pieces of hardware, like if they needed to complete a crew vehicle or a transit vehicle by a certain date, the spike would allow that to be done on schedule.

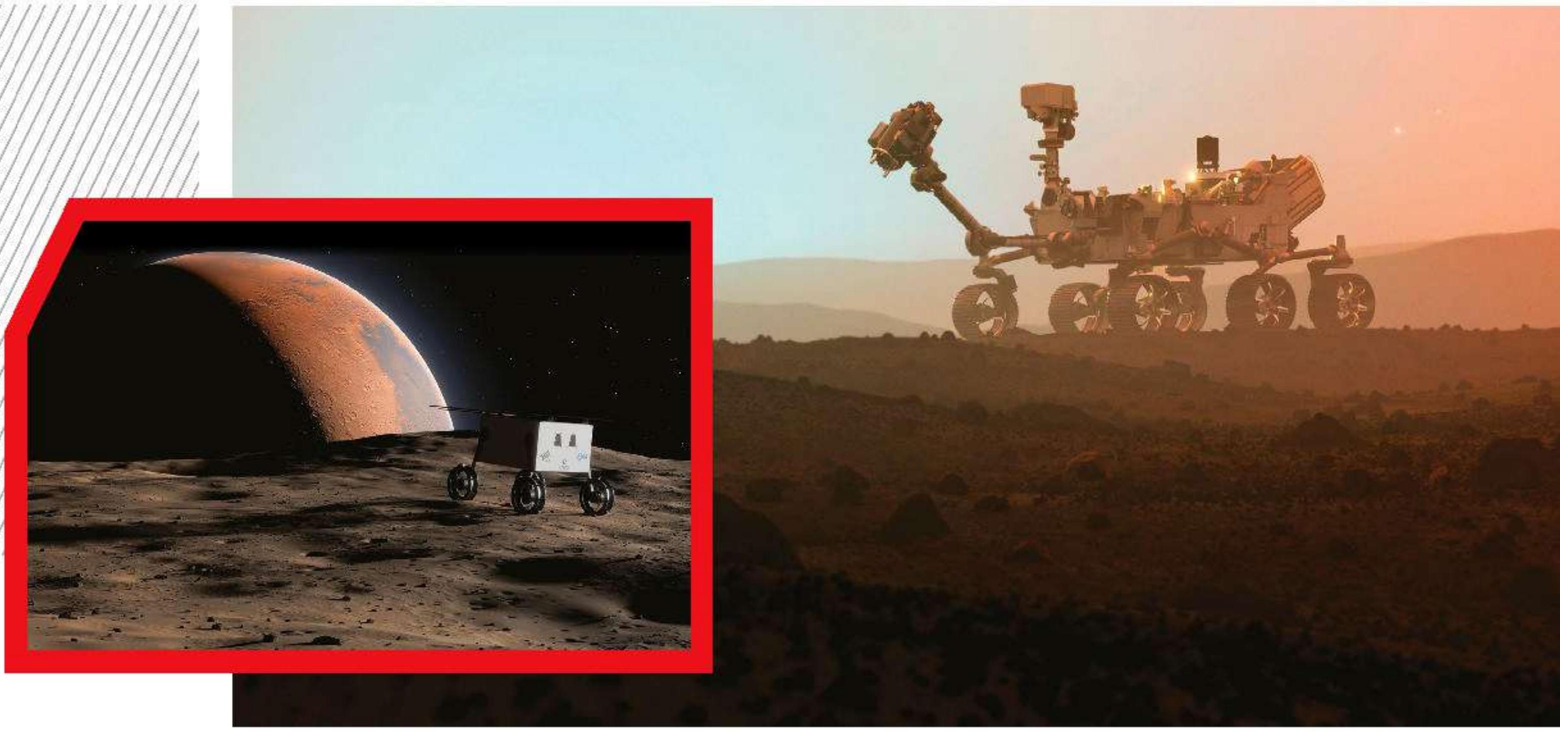
How much would it cost?

When you're talking about plans over the next 20 years, it's always challenging to get the cost accurate, but Explore Mars has been working with a number of other groups to try and determine the probable cost of such missions. We've run several 'affording Mars' workshops, which have resulted in the release of our 'Humans to Mars' report. We brought together most of the key experts with some international participation, although not a lot, as well as academia, to review whether we could go to Mars affordably.

After many discussions, we agreed that it can be done affordably. We can't provide an exact amount, but it isn't going to cost remotely anywhere near what many of the pundits are saying. Even recently I have heard numbers ranging from half a trillion dollars to 1.5 trillion dollars, and it shouldn't cost anywhere near close to that. Most of those numbers are thrown out there by opponents of going to Mars to try to scare people into not supporting a mission.

Can you tell us a little bit more about the other work Explore Mars does?

Explore Mars is a US-based nonprofit corporation that was founded in 2010. We're not a membership group, but instead we run technical projects. One is called ExoLance, which is developing penetrator probes to try and get below the Martian surface to do experiments, and potentially look for life as well. We are also doing a student project called Time Capsule to Mars, where



A Phobos rover could snap photos from the moon

It's hard enough landing a rover on Mars, let alone a craft carrying human passengers we're trying to send a small cubesat to Mars and drop a tiny digital time capsule onto the surface.

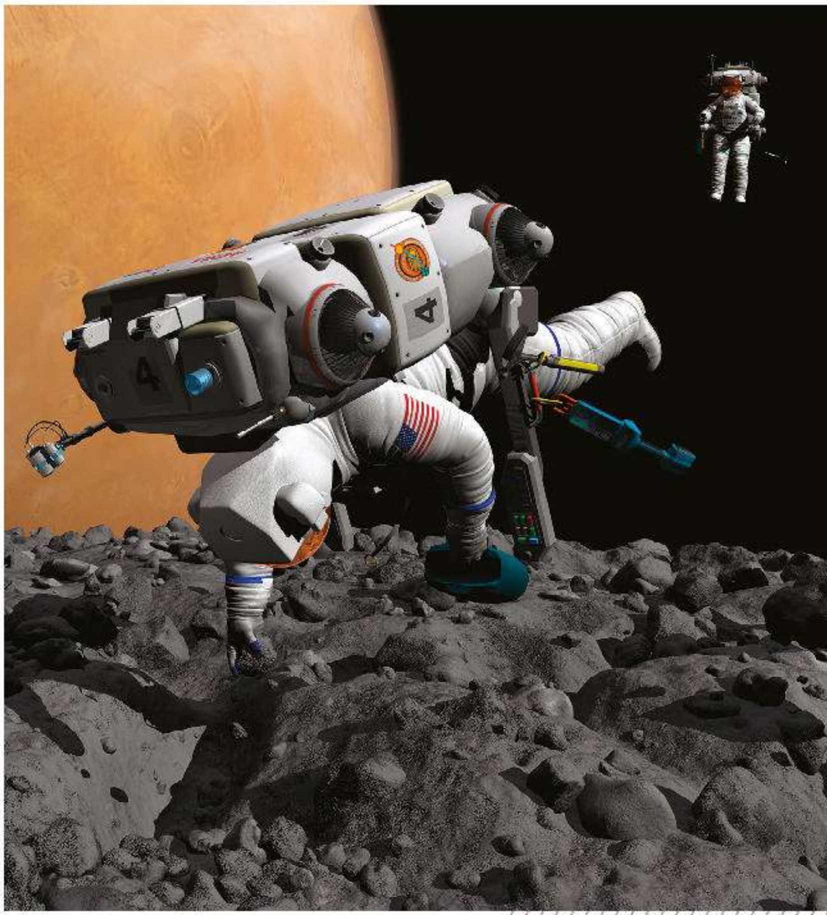
We do a lot of programs like the Humans to Mars summit, which is the biggest annual conference dedicated to human missions to Mars, and we do a lot of topical workshops, all to bring the space community together to try and build a coalition and try to solve some of the problems that have kept the different Mars groups apart over the last several years. We also do science and technology education programs as well. We do a wide range of activities, as well as policy work for trying to advance the goal of getting humans on the surface of Mars by the mid-2030s.

Our founders, including myself, used to be with the Mars Society. I was actually the executive director of the Mars Society for a few years, and we're still good friends with a lot of people there, but we haven't collaborated much over time, and I think it's time to interact more with them. What makes our organisation succeed is that we collaborate with a large number of different groups within the space community and also groups that are not related to space.

Will astronauts actually land on the surface of Phobos?
Not Phobos. It doesn't have much gravity, so it wouldn't be practical to colonise. Popular opinion is that Phobos and Deimos are actually captured asteroids, so we could use them for other things instead of setting up a base. First off, we could do Mars sample-return missions from either moon because there is a lot of debris from Mars on those moons. This is because over billions of years Mars shot up debris from the surface thanks to now-dormant or extinct volcanoes and meteorite impacts, so scientists think we could find an awful lot of samples of Mars on the surface of Phobos and Deimos using robots to search for them. Another reason scientists want to go to the moons is to better understand asteroids.

One of the discussions we've had in the US for over a decade now is whether we should stop at an asteroid before going to Mars. If you go to Phobos or Deimos you're killing two birds with one stone, because if they are asteroids you can learn about both Mars and about small asteroidal bodies by going to them. To land a robot on Phobos, you would need some kind of system of harpoons and drills like the lander on the Rosetta probe had and do a lot of thruster moves because there isn't enough gravity to land like you would on Mars.

Will astronauts go to Mars directly from Phobos?
For the first mission they would certainly not go to the surface of Mars and the surface of Phobos on the same visit – it's not even certain they would go to the surface of Phobos, just into orbit. Based on the JPL plan, it would be several years before they land on Mars, and they wouldn't stop at Phobos along the way in that second mission. The main goal is to get onto the surface of Mars, and even JPL folks who have talked about going to Phobos or orbiting Mars in general, their goal is to get to the surface, but we figure that we need to have at least one stepping stone along the way to allow them to test out key technologies.


Astronauts could return Phobos samples for Earth analysis

© Getty

"Popular opinion is that Phobos and Deimos are actually captured asteroids"

Will current spacecraft orbiting Mars select the landing site, or will this be done closer in time to the landing by future orbiters?
The European Space Agency is actually beginning to review potential landing sites even at this stage, despite landing on Mars not being likely to take place until after 2035. But either the current satellites we have around Mars or the ones that come after will help choose the landing site, and hopefully in the next 20 years we'll have far more advanced orbiters that can take much more detailed photographs and much more accurate readings of the climate and the chemical nature of the Martian atmosphere, which we already have a good sense of. It will be interesting to see what spacecraft we will have around Mars in advance of sending humans.

FOCUS ON

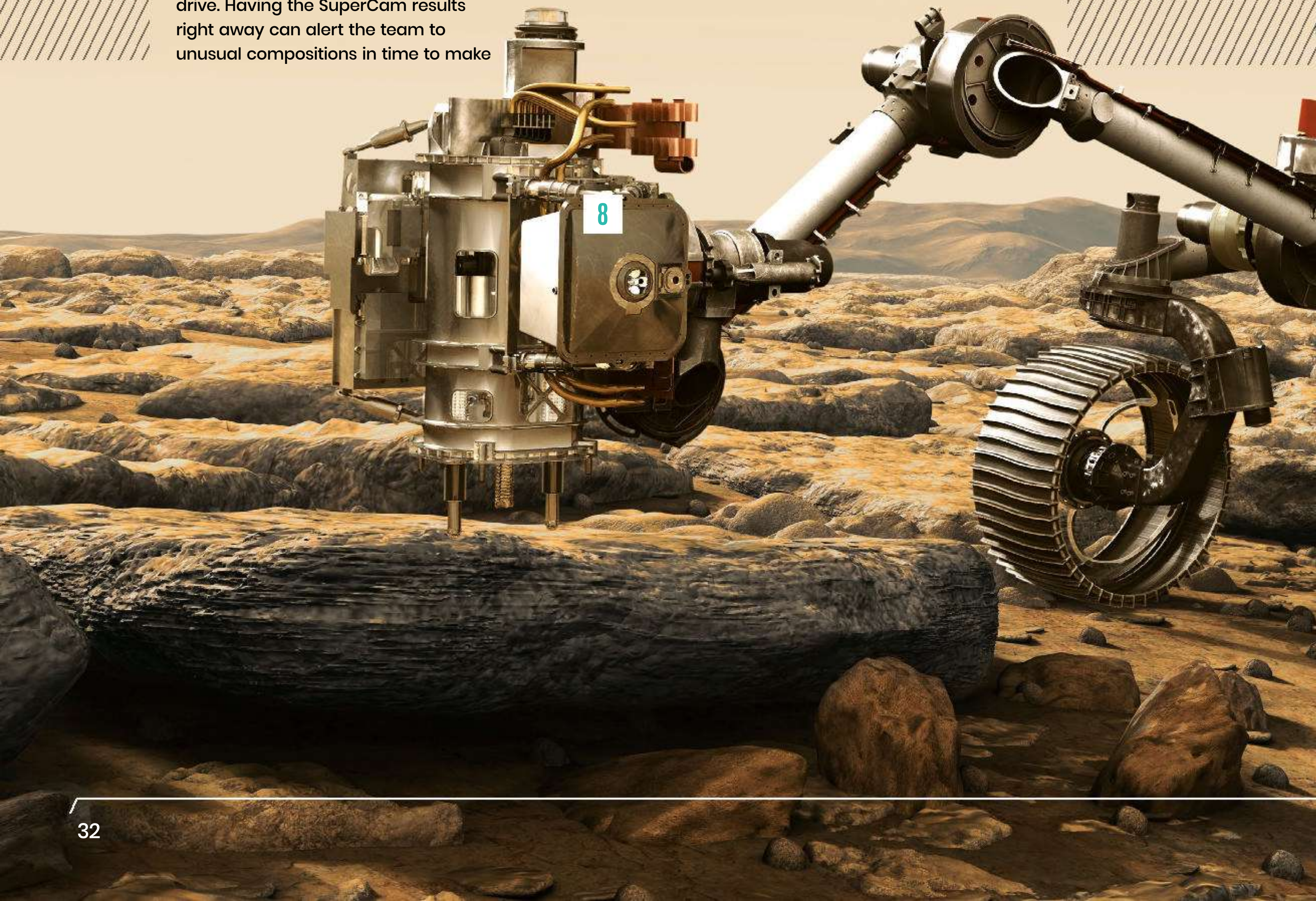
MARS ROVER PICKS ITS OWN ROCK SAMPLES

Perseverance is analysing each sample's elemental composition in the ongoing search for ancient life

Reported by Elizabeth Howell

NASA is hailing the Perseverance rover's improved ability to pick its own targets as a way of speeding up science on Mars. Without explicit direction from Earth, the Perseverance rover zapped two rock targets with its SuperCam instrument on Sol 442 (18 May 2022) to learn more about their elemental compositions, mission scientists said in an update on 31 May. "Normally when the rover team picks the targets, observations aren't made until the following day," Roger Wiens, principal investigator of SuperCam and a planetary scientist at Los Alamos National Laboratory, said. "If Perseverance picks its own targets, it can shoot them right after a drive. Having the SuperCam results right away can alert the team to unusual compositions in time to make decisions about further analyses before the rover moves on," Wiens added.

Perseverance's software for target selection is called Autonomous Exploration for Gathering Increased Science (AEGIS) and was developed at NASA's Jet Propulsion Laboratory in California for other rover missions. The software was then adapted for Perseverance's SuperCam instrument. "AEGIS requests Navigation Camera (Navcam) images to be taken, and it then analyses the images to find rocks and

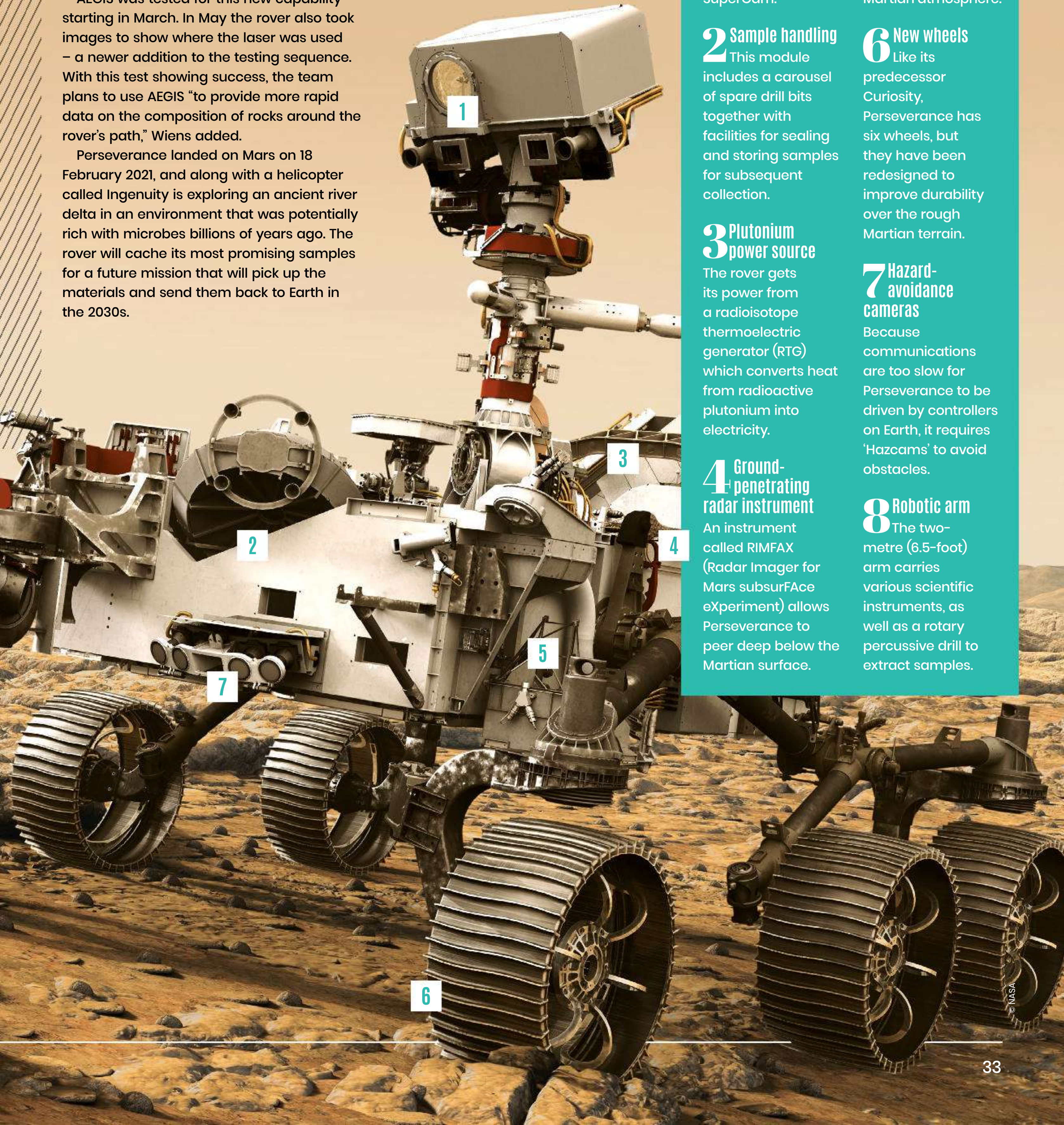


prioritise them for analysis based on size, brightness and several other features," Wiens said. "It subsequently initiates a sequence in which SuperCam fires its laser to determine the chemical make-up of one or two top-priority targets selected from Navcam images."

AEGIS was tested for this new capability starting in March. In May the rover also took images to show where the laser was used – a newer addition to the testing sequence. With this test showing success, the team plans to use AEGIS "to provide more rapid data on the composition of rocks around the rover's path," Wiens added.

Perseverance landed on Mars on 18 February 2021, and along with a helicopter called Ingenuity is exploring an ancient river delta in an environment that was potentially rich with microbes billions of years ago. The rover will cache its most promising samples for a future mission that will pick up the materials and send them back to Earth in the 2030s.

> "It analyses images to find rocks and prioritise them for analysis based on size, brightness and several other features" **Roger Wiens**



© NASA

1 Camera mast

The mast carries an array of cameras, some for navigation and some for scientific analysis, including the laser-firing SuperCam.

2 Sample handling

This module includes a carousel of spare drill bits together with facilities for sealing and storing samples for subsequent collection.

3 Plutonium power source

The rover gets its power from a radioisotope thermoelectric generator (RTG) which converts heat from radioactive plutonium into electricity.

4 Ground-penetrating radar instrument

An instrument called RIMFAX (Radar Imager for Mars subsurFAce eXperiment) allows Perseverance to peer deep below the Martian surface.

5 MOXIE

The Mars OXygen In-situ resource utilization Experiment is testing a method for producing oxygen from CO_2 in the Martian atmosphere.

6 New wheels

Like its predecessor Curiosity, Perseverance has six wheels, but they have been redesigned to improve durability over the rough Martian terrain.

7 Hazard-avoidance cameras

Because communications are too slow for Perseverance to be driven by controllers on Earth, it requires 'Hazcams' to avoid obstacles.

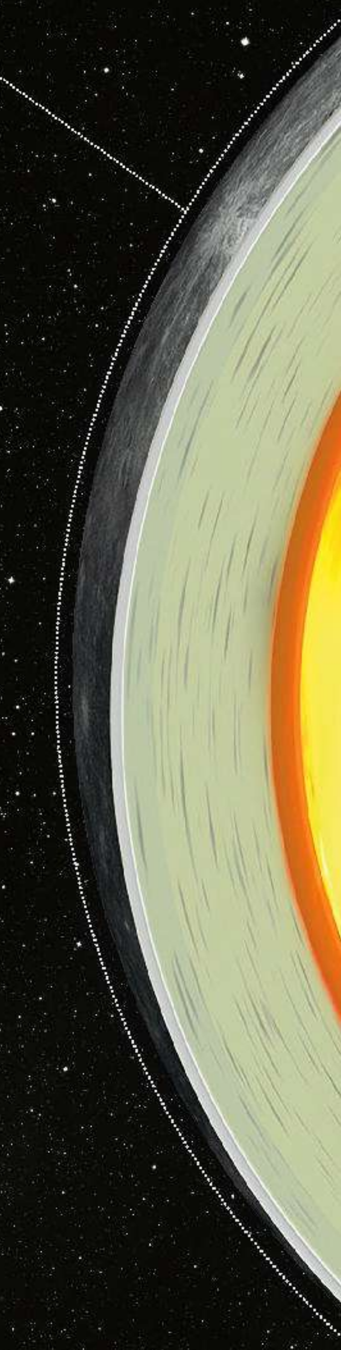
8 Robotic arm

The two-metre (6.5-foot) arm carries various scientific instruments, as well as a rotary percussive drill to extract samples.

PLANET PROFILE

MERCURY

This minute world is arguably the least explored of the four terrestrial planets



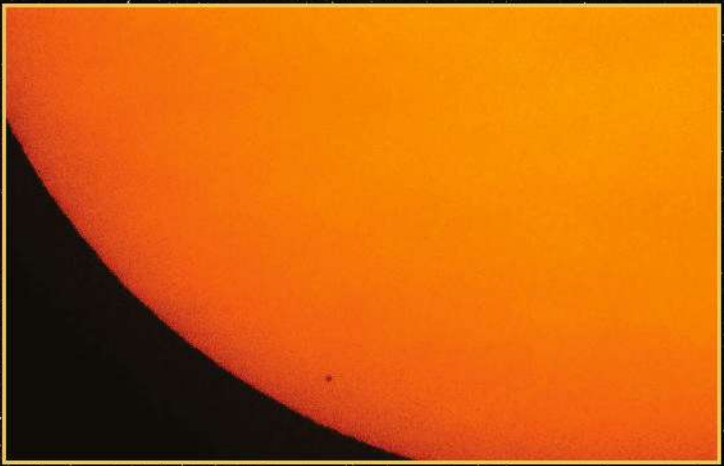
Mercury is the smallest of all the planets in the Solar System and the closest planet to the Sun, but there's so much more to it. Mercury is so tiny compared to the other planets that you can actually fit around 23,500 Mercurys into Jupiter, though it's roughly 1,400 kilometres (870 miles) larger in diameter than the Moon.

The small planet orbits the Sun with less than half the distance between the Sun and Earth, resulting in it being 'tidally locked'. Tidal locking occurs when an object is so close to its host that the gravity is overwhelmingly powerful; because of this influence, instead of continuously spinning on its axis like Earth does, the object has one side facing towards its host object at all times. In this case Mercury is tidally locked to the Sun. For every two revolutions around the Sun, Mercury rotates on its axis three times. Each orbit takes 88 Earth days, making a year on Mercury roughly a quarter of an Earth year.

As Mercury is so close to the Sun, the surface temperatures can be scorching, reaching highs of 450 degrees Celsius (840 degrees Fahrenheit). Enduring this bombardment of solar radiation, the planet also struggles to keep hold of its atmosphere, meaning that no heat is trapped. This means the nightside of the planet – the one facing away from the Sun – can have temperatures as low as -180 degrees Celsius (-290 degrees Fahrenheit).

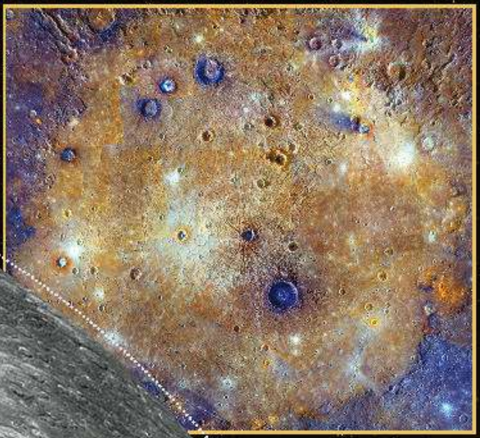
While Mercury is a similar size to the Moon, it's also similar in appearance. It's a heavily cratered, rocky body with some of the largest craters in the Solar System. One such crater studied by previous exploration missions is a great example. The Caloris Basin, which is roughly 1,550 kilometres (960 miles) wide, is about the size of Texas and was formed when an asteroid about 100 kilometres (60 miles) across hit Mercury's surface 4 billion years ago, impacting the planet with energy equivalent to a trillion one-megatonne bombs.

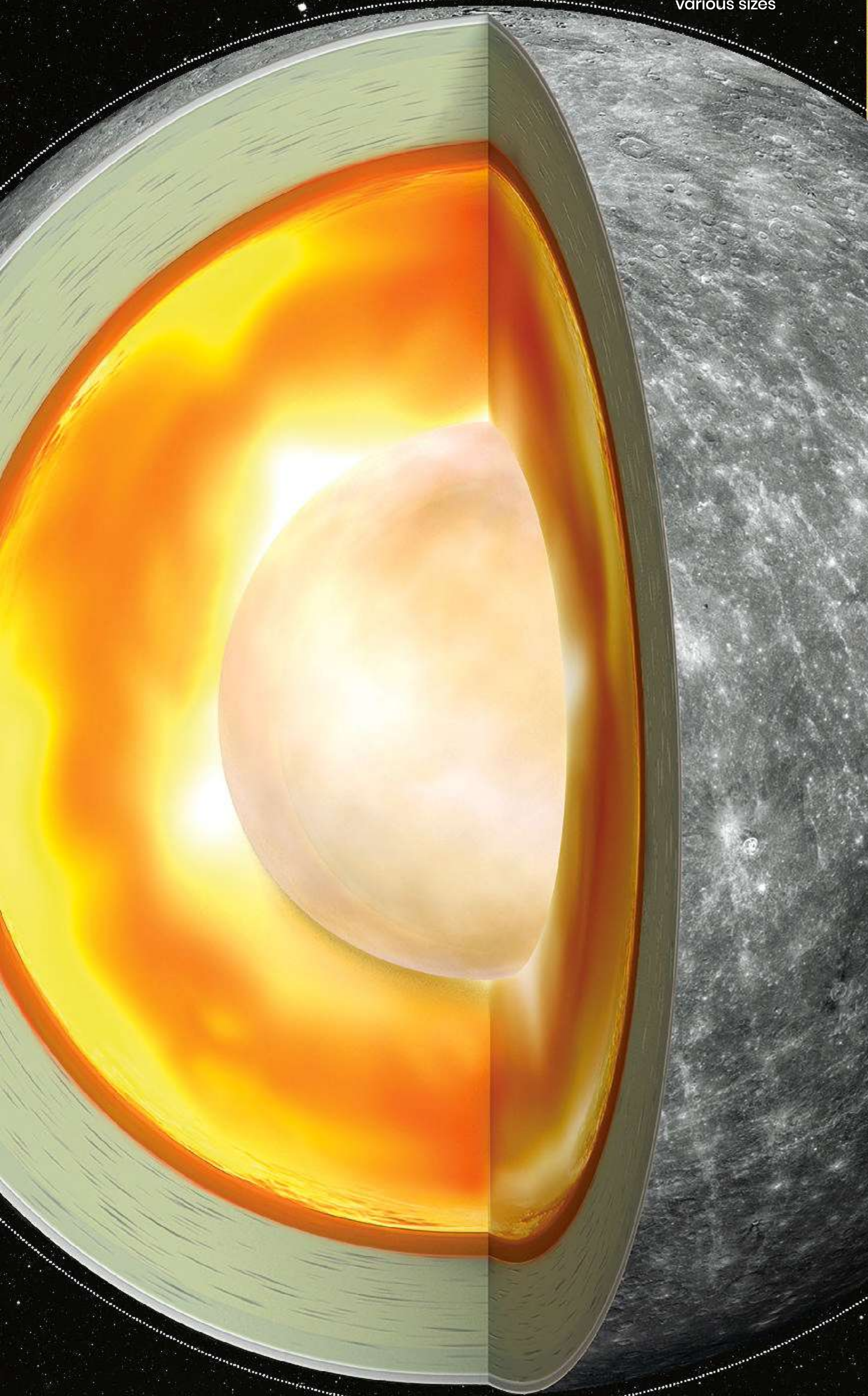
If you scratch beneath the surface, the true weirdness of Mercury starts to become apparent. Under the ultra-thin cratered crust is an extremely dense planet, with somewhere between 70 and 85 per cent of the planet being an enormous iron core. Astronomers have spent years constraining whether it's solid, molten or both, and they seem to agree it has a solid iron core with an outer molten core. Astronomers believe that a molten core explains Mercury's very weak magnetic field. After data was brought back from NASA's Mariner 10 and MESSENGER (Mercury Surface, Space Environment, Geochemistry and Ranging) space probes and analysed, astronomers posited that Mercury is the exposed core of a much larger planet, with its outer layers lost to a powerful collision billions of years ago.



During its 88-day orbit, Mercury will sometimes pass in front of the Sun as viewed from Earth in a planetary transit

The surface of Mercury is pockmarked with craters of various sizes





Atmospheric composition

42%
Oxygen

29%
Sodium

22%
Hydrogen

6%
Helium

0.5%
Potassium

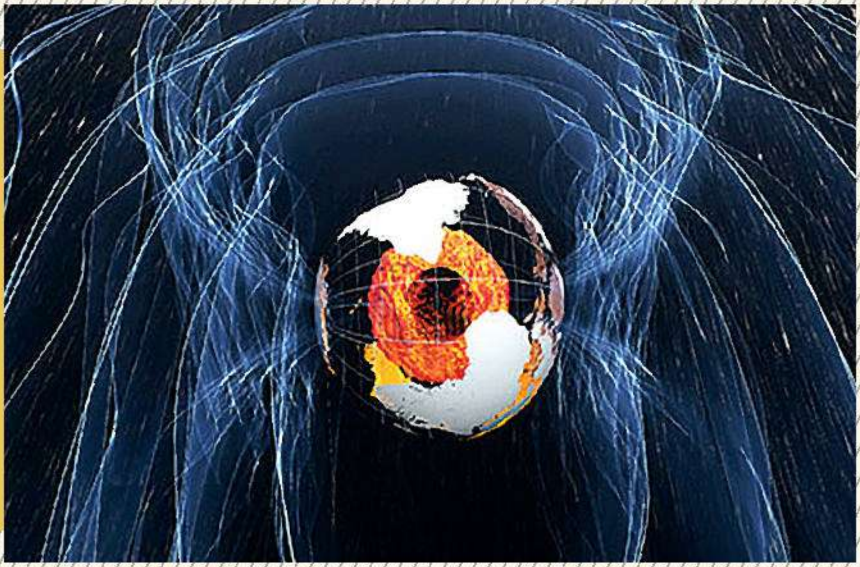
+ Traces of argon, carbon dioxide, water, nitrogen,

© NASA

NEWS FROM MERCURY

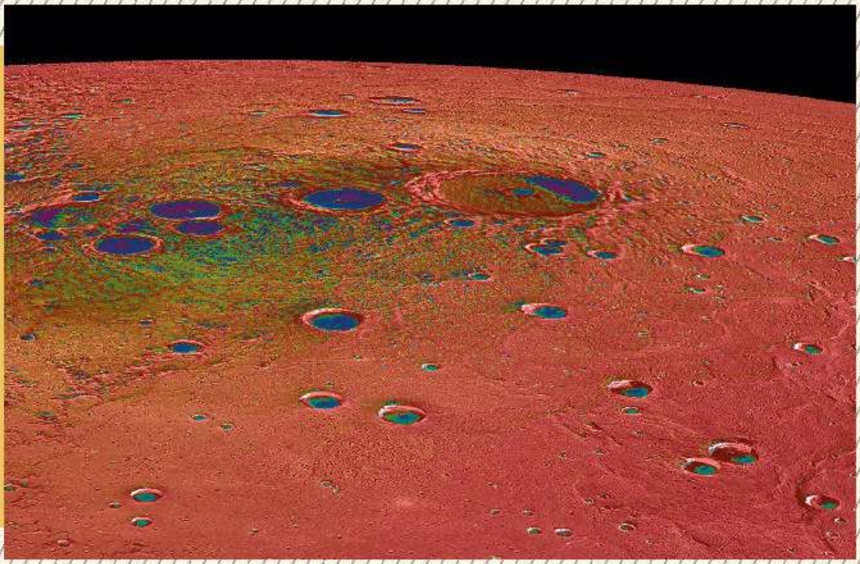
Magnetic irregularities

A magnetic field is the result of the motion of a molten core. Earth's magnetic poles have been known to shift, but astronomers have suggested that Mercury's have been doing the same. Mercury's ancient magnetic poles, known as palaeopoles, appear to have shifted over time, and could present clues in the investigation of Mercury's interior. By understanding the magnetic field, we could pinpoint the nature of the planet's molten core. Results came from MESSENGER data on ancient craters that had irregular magnetic signatures. Not only would a further analysis help us understand the nature of Mercury's interior, it could have implications for understanding how the planet evolved, and even how Earth's magnetic field evolved.



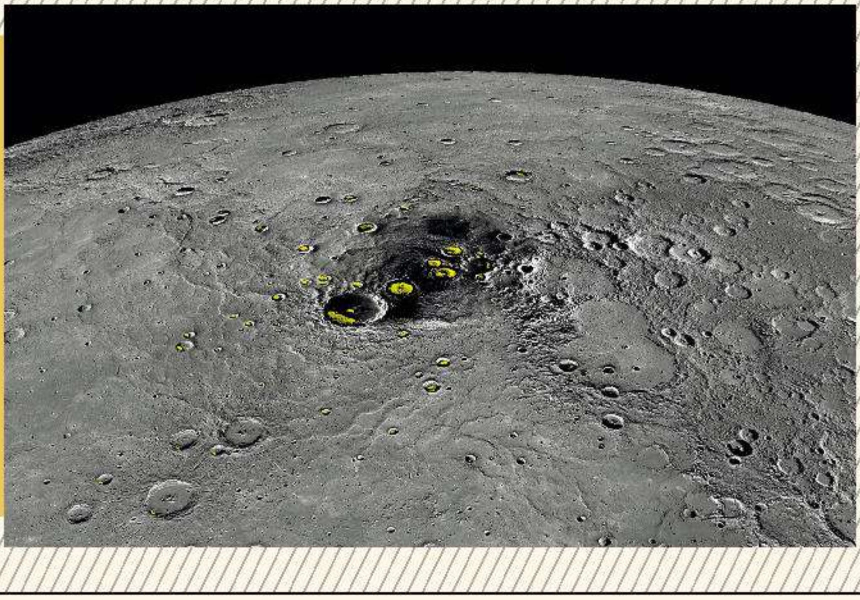
Insulating iron sulphide

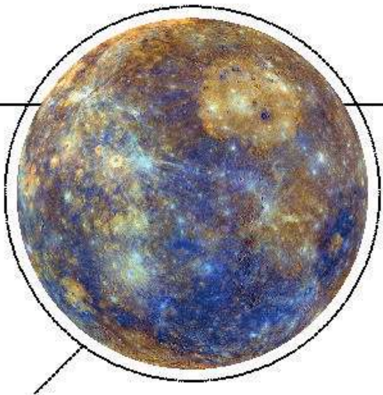
Once again Mercury's magnetic field is the centre of research. Instead of trying to understand its nature, astronomers are trying to understand how it's kept in place. Astronomers have seen with Mars how a planet smaller than Earth can solidify its molten core, consequently losing its magnetic field, but Mercury still appears to have one. Recent research suggests that a layer of iron sulphide could be insulating the core, maintaining its molten state. Experiments predict that Mercury has a solid inner core with a molten outer core of iron, sulphur and silicon. These elements can't mix, so the iron and sulphur compounds were expelled towards the outer regions of the planet, creating an insulating layer.



Searching for water ice

Mercury may be hiding water at its poles, with MESSENGER revealing the signatures of thick deposits of water ice hidden in craters at the planet's poles. Sunlight doesn't reach the craters' depths, so they're sheltered from the radiation that causes water ice to dissipate. Astronomers believe these craters could hold answers about where water is dispersed in the Solar System. Astronomers have also been comparing Mercury and the Moon to try and understand what the water ice in these craters may look like. This involved looking at around 14,000 craters on the two bodies. The conclusion was that on Mercury, craters that harbour ice have shallower sides than those that don't.





BEPICOLOMBO'S SEVEN-YEAR JOURNEY TO MERCURY

Date: 20 October 2018
Activity: Launch from Earth.

Date: 10 April 2020
Activity: Earth flyby.

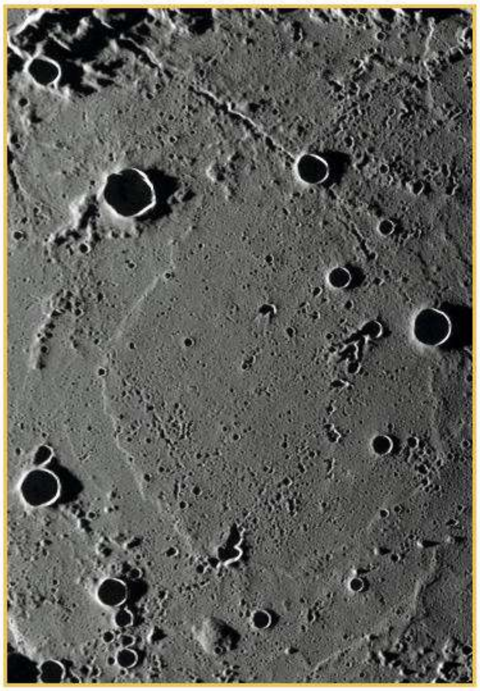
Date: 15 October 2020
Activity: First Venus flyby.

Date: 10 August 2021
Activity: Second Venus flyby.

Date: 1 October 2021
Activity: First Mercury flyby.

Date: 9 January 2025
Activity: Sixth and final Mercury flyby.

Date: 5 December 2025
Activity: Orbital insertion around Mercury.



FACTS ABOUT MERCURY

NASA's MESSENGER mission stayed in orbit around Mercury from March 2011 to April 2015 before crashing into the surface of the planet

59

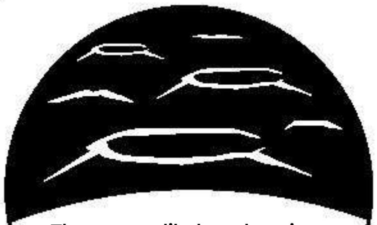
One day on Mercury lasts 59 Earth days, while a year on Mercury lasts just 88 Earth days

Mercury's atmosphere is more comparable to a 'thin exosphere' as it's comprised mostly of atoms ejected from the surface due to the solar wind and meteoroid impacts

On Mercury's nightside at the right time of year, there's a faint orange glow from the sodium scattered by sunlight

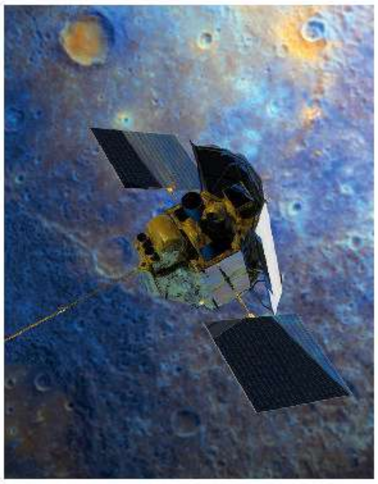
0

Mercury is one of two planets in the Solar System with no moons



There was likely volcanism on Mercury – there are areas that appear to have been flooded with lava

EXPLORING THE PAST AND FUTURE OF THE SWIFT PLANET



Visiting Mercury is a dangerous and difficult task. Navigating a spacecraft here requires propulsion that will get it to Mercury but also counteract the gravity of the Sun so the craft doesn't go falling into its surface and burn up. This is why only two spacecraft have ever visited the small planet. NASA has been the operator of both of these, the first being Mariner 10 in 1974, which conducted a series of flybys and gathered close-up images.

The mission that brought the most fascinating results is MESSENGER – the first and only spacecraft to orbit the planet. MESSENGER's most important results included how volatile-rich the planet was – volatiles being chemical compounds with low boiling points – which has important implications for the planet's formation. It also found ice deposits at the poles, the weird magnetic field offset and irregular depressions called 'hollows'.

BepiColombo, a joint endeavour by the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA) will arrive at Mercury in 2025, where it will separate into two orbiters and use its impressive instrumental suite to investigate the planet from all angles. This unique mission will have its two orbiters working simultaneously as scientists get up-close observations of the surface and more distant observations of the magnetic field.

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FOCUS ON

WOBBLY SPACE JETS MAY AFFECT ALIEN LIFE

Binary star protoplanets could form differently due to infalling material

Reported by Stefanie Waldek

Because Earth is the only planet known to host life as we know it, researchers have usually focused on planetary systems similar to our own when searching for extraterrestrial life. But new research suggests that planetary systems form differently around binary stars than they do around lone stars like the Sun, and those differences could affect the potential for a binary star system to support life.

Nearly 50 per cent of all Sun-size stars are binary stars, so if the new theory is confirmed, it could double the number of systems that researchers might want to probe. "The result is exciting since the search for extraterrestrial life will be equipped with several new, extremely powerful instruments within the coming years," lead scientist Jes Kristian Jørgensen, a professor of astrophysics and planetary science at the Niels Bohr Institute at the University of Copenhagen, said. "This enhances the significance of understanding how planets are formed around different types of stars. Such results may pinpoint places which would be especially interesting to probe for the existence of life."

The recent study was based on observations of the young binary star system NGC 1333-IRAS2A using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile. That system, located about 1,000 light years away, is enveloped in a disc of gas and dust that could one day create a planetary system. The team then created simulations that allowed them to rewind and fast-forward the life cycle of the system. They discovered that the movement of the gas and dust was not continuous. "At some points in time – typically for relatively short periods of 10 to 100 years every thousand years – the movement becomes very strong," the researchers described. "The binary star becomes 10 to 100 times brighter until it returns to its regular state."

The team theorised that at certain points in the stars' orbits around each other, their gravity pulls material from the gas and dust disc onto the surfaces of the stars. In turn, these bursts of infalling trigger wobbly jets shooting out from the disc. "The falling material will trigger significant heating," said Rajika L. Kuruwita, a postdoctoral researcher at the Niels Bohr Institute. "These bursts will tear the gas and dust disc apart. While the disc will build up again, the bursts may still influence the structure of the later planetary system." Solo stars like the Sun probably wouldn't have gone through a similar process, likely meaning that planets form differently around solo stars than they do around binary stars, the team said.

Researchers also plan to investigate the possible role of comets in planetary system formation, as comets carry organic molecules that could jump-start extraterrestrial life on an otherwise barren planet. While the team hopes to continue their observations with ALMA, they're looking forward to tapping into the next generation of telescopes, including the James Webb Space Telescope, Europe's Extremely Large Telescope and the Square Kilometre Array, all of which will begin operations within the next few years. "Combining the different sources will provide a wealth of exciting results," Jørgensen said.

> "The search for extraterrestrial life will be equipped with several new, extremely powerful instruments within the coming years"
>
> **Jes Kristian Jørgensen**

CONDITIONS FOR A HABITABLE EARTH-LIKE PLANET

1 Under 1.6 times the size of Earth

Astronomers have proven that planets up to 1.6 times the size of Earth generally follow the same processes that made our home planet.

2 Magnetic shield

To deflect space radiation and storms from its parent star, an Earth-like planet needs a magnetic field. This also ensures the atmosphere doesn't whittle away.

3 Just the right temperature

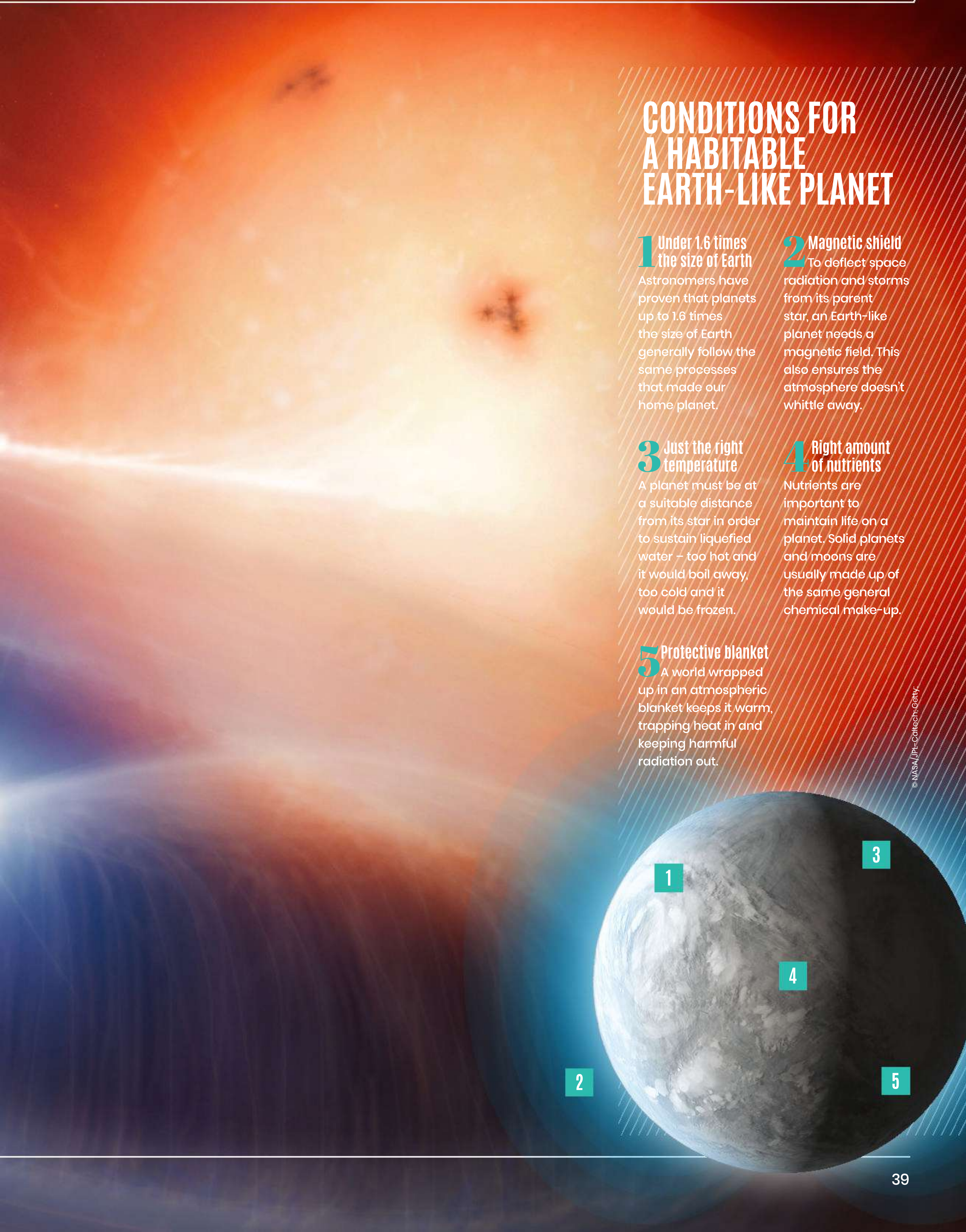
A planet must be at a suitable distance from its star in order to sustain liquefied water – too hot and it would boil away, too cold and it would be frozen.

4 Right amount of nutrients

Nutrients are important to maintain life on a planet. Solid planets and moons are usually made up of the same general chemical make-up.

5 Protective blanket

A world wrapped up in an atmospheric blanket keeps it warm, trapping heat in and keeping harmful radiation out.



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INSTANT EXPERT

HOW ARE GALAXIES MADE?

What enables these behemoth structures to come into existence

Galaxies are tremendous clusters of billions to trillions of stars, and are where the majority of stars reside. If you're fortunate enough to have a dark night sky, you will be able to see a section of our own galaxy, the Milky Way, as a ribbon of stars stretching across the sky. The Milky Way is estimated to be roughly 100,000 light years across, containing some 100 billion stars, and is probably a barred spiral rather than the classic swirl we think of as a galaxy. Our nearest galactic companion, the Andromeda Galaxy, is even bigger, containing up to a trillion stars, but how do these massive structures come to form?

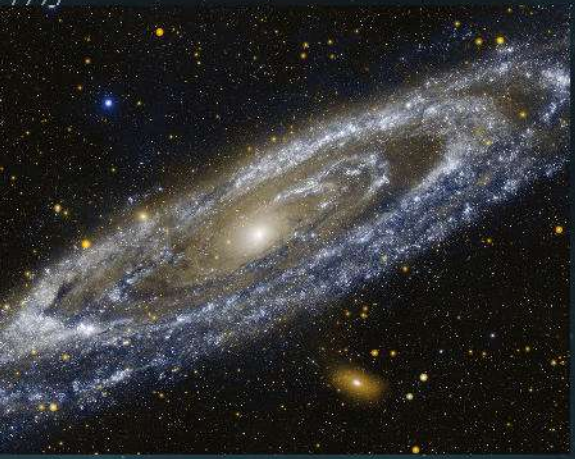
There are two major shapes that a galaxy can form. Elliptical galaxies are fuzzy clouds of stars, whereas spiral galaxies are the classic image of a galaxy with a number of arms wrapped around a centre. Different mechanisms may be at play in the different shapes, but broadly the theories are either 'top down' or 'bottom up'. Top-down formation would be very similar to the way we believe stars form – a large, cold cloud of gas and dust starts to contract, warming up and starting to spin as it does so. Once the centre of the cloud gets dense enough, stars would start to form in smaller versions of this process, with their own small eddies forming planets around them.

In bottom-up formation, stars would form first from the general background material of the Big Bang. As the first ones became established, their presence would start to attract other stars and indeed set off the formation of other stars as the density of material increased. It may be that elliptical galaxies form one way and spirals form another, or that ellipticals began with clouds that were spinning slowly and spirals with clouds spinning quickly.

BIO
ROBIN HAGUE

Hague is a science writer, focusing on space and physics. He is the current head of launch at Skyrora, coordinating launch opportunities for Skyrora's vehicles and liaising with UK launch regulators.

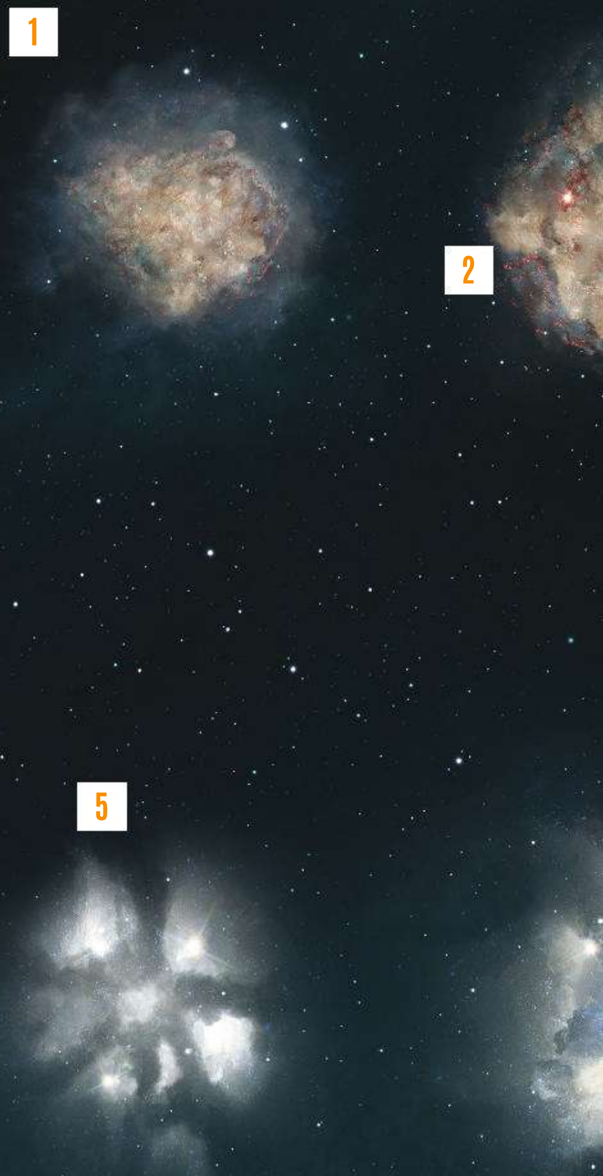
Another factor that we know from observation affects the development of galaxies is collision. Despite the massive distances between them, galaxies are proportionately closer together than stars are. As a result we can see a number of galactic collisions occurring in the universe, and it's believed our own Milky Way has collided with other smaller galaxies. Although there's a huge amount of matter in galaxies, these collisions aren't actually impacts. Because there is so much space between stars, meeting galaxies actually pass through each other. It's the gravitational interaction of their matter that can mingle them together into a new whole. Galaxies themselves are not randomly scattered through space, but are grouped together into long filament-like clusters; these are the largest structures we have identified and probably indicate variations in density in the very early universe.



Spiral galaxies have distinct arms where star formation is more active

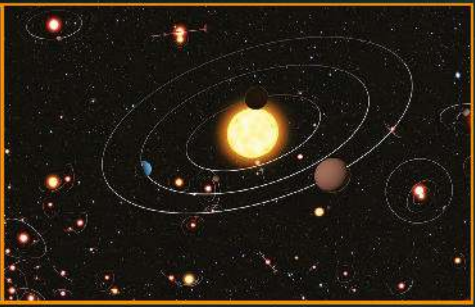
1 Uniform cloud
With top-down formation, a relatively uniform cloud of material would slowly start to contract.

2 First star formation
As the density of material increases, the first stars start to form in smaller collapses in the cloud.



SPREAD OF LIFE

Just 30 years ago we were unsure if there were planets around other stars; now we have found thousands of them – and they're just the ones that are easiest to find. A study by NASA based on data from the planet-hunting Kepler telescope estimates that there could be around 2 billion planets like Earth in the Milky Way alone. If the 50 billion galaxies we can see have the same concentration, there could be 100 quintillion Earths out there.



3 Spin

As the cloud contracts, it will begin to spin – random collisions end up favouring one direction or another.

4 Spiral structure

The rotation of the cloud will flatten it into a disc, which itself can separate into sweeping spiral arms.

5 Bottom up

In bottom-up formation, stars would first start to form from variations in the overall universe.

6 Clustering

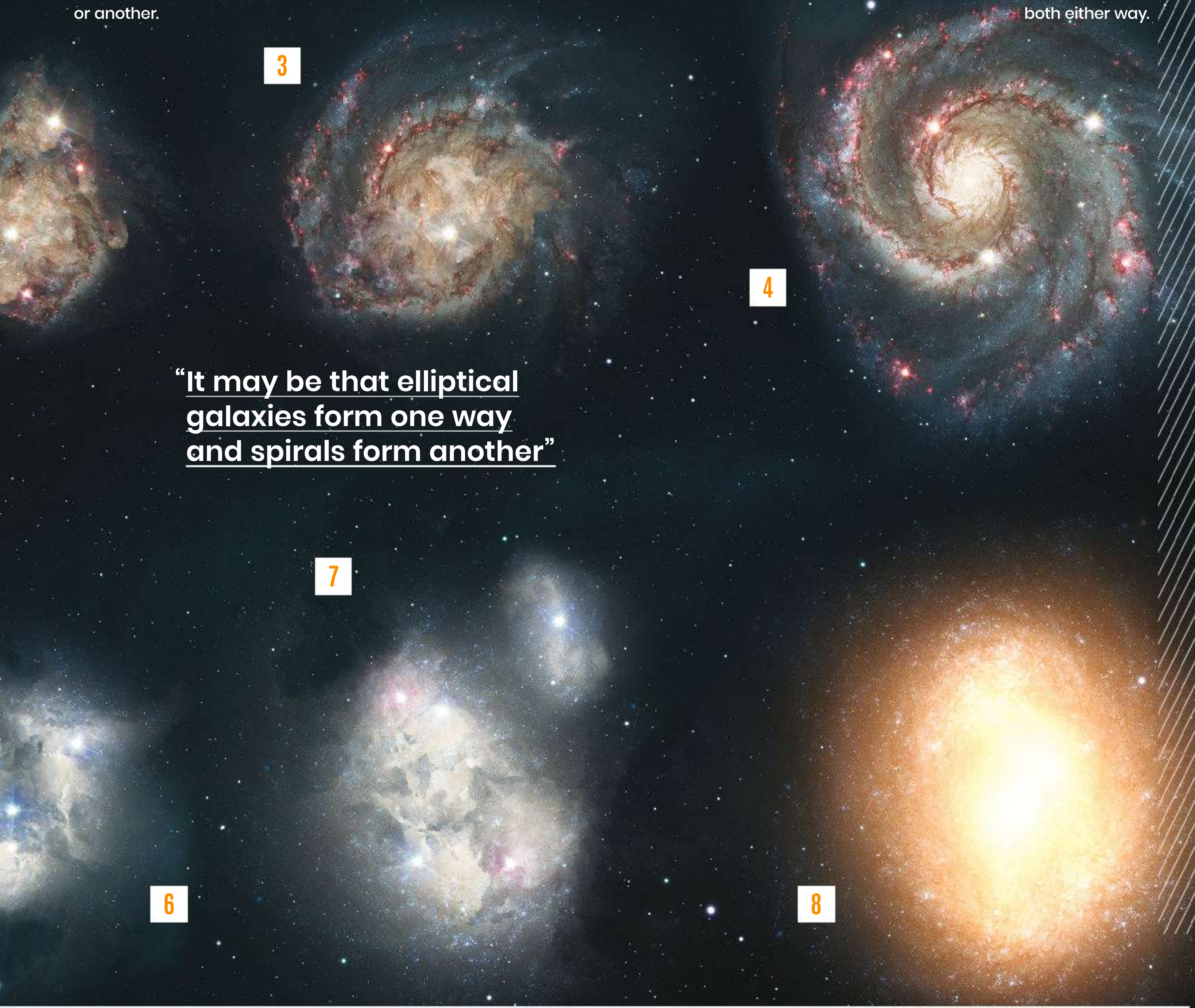
As more stars form, they would start to interact with each other and begin to form a group.

7 Galaxy formation

Eventually, enough stars come together to form a galaxy, establishing a galactic rotation.

8 Elliptical structure

Spiral and elliptical galaxies might not form in different ways; it may be possible to produce both either way.



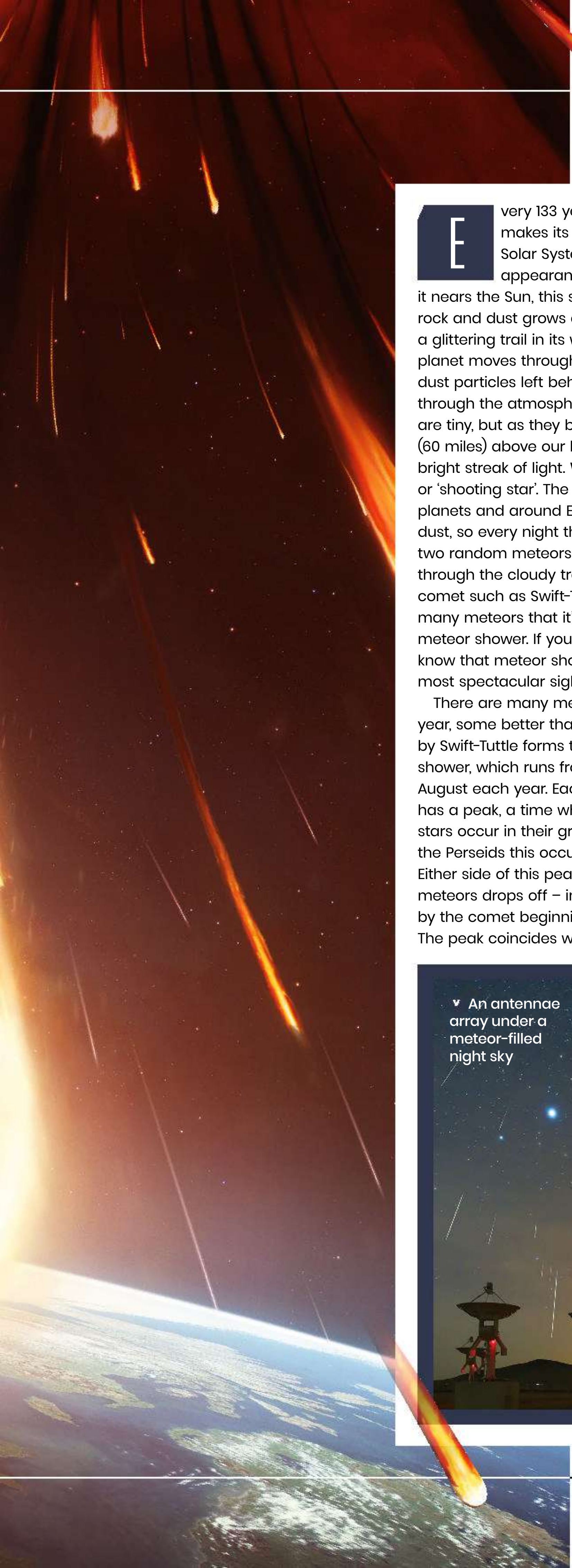
> "It may be that elliptical galaxies form one way and spirals form another"

© NASA; ESO; Tobias Roetsch

COMETS, ASTEROIDS & METEOR SHOWERS

Racing through space and crashing into Earth's atmosphere, All About Space discovers the space rocks that litter our Solar System

Reported by Colin Stuart



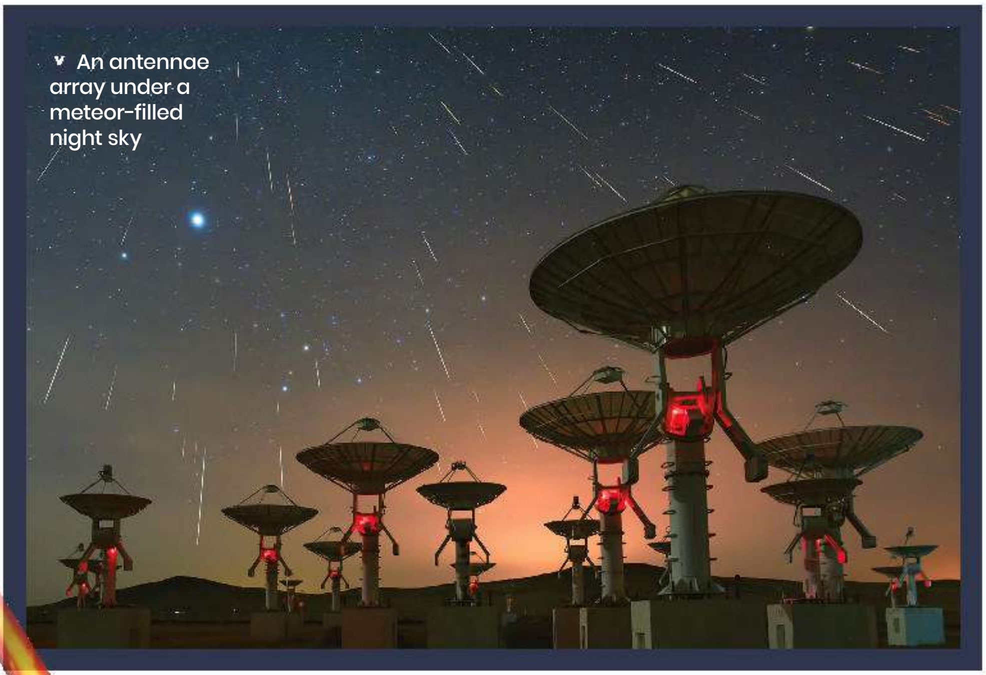
Every 133 years, Comet Swift-Tuttle makes its return to the inner Solar System. It last made an appearance in 1992. Each time it nears the Sun, this speeding ball of ice, rock and dust grows a tail that deposits a glittering trail in its wake. Every year our planet moves through this, causing the dust particles left behind to come crashing through the atmosphere. Most of them are tiny, but as they burn up 100 kilometres (60 miles) above our heads they leave a bright streak of light. We call this a meteor, or 'shooting star'. The space between the planets and around Earth's orbit is full of dust, so every night there will be one or two random meteors. When Earth travels through the cloudy trail of dust left by a comet such as Swift-Tuttle, there are so many meteors that it's described as a meteor shower. If you've seen one, you'll know that meteor showers are among the most spectacular sights in the night sky.

There are many meteor showers each year, some better than others. The dust left by Swift-Tuttle forms the Perseid meteor shower, which runs from 17 July to 24 August each year. Each meteor shower has a peak, a time when the shooting stars occur in their greatest number. For the Perseids this occurs on 12 August. Either side of this peak, the number of meteors drops off – imagine the trail left by the comet beginning to spread out. The peak coincides with the densest part of the trail, and the most active meteor showers can produce more than 100 shooting stars per hour.

Other great meteor showers include the Quadrantids in January, which peak on the 3rd; the Lyrids between 16 and 25 April; the Orionids that peak on 21 October; the Leonids that are at their maximum on 17 November and the Geminids, which are at their best on 14 December. The names of the meteor showers come from the constellations in which they appear to streak from – this is the direction in which Earth is moving through the dust trails. For example, the Perseids streak across the sky from their 'radiant' in Perseus, the Leonids from Leo and the Geminids from Gemini.

The Geminids are unique among meteor showers. All the rest are produced by dust from comets, but the Geminids are produced by dust left by an asteroid, 3200 Phaethon. This goes to show that sometimes the lines between asteroids and comets can be blurred. Astronomers have even witnessed some asteroids in the asteroid belt acting like comets by growing a tail.

"If you've seen one, you'll know that meteor showers are among the most spectacular sights in the night sky"



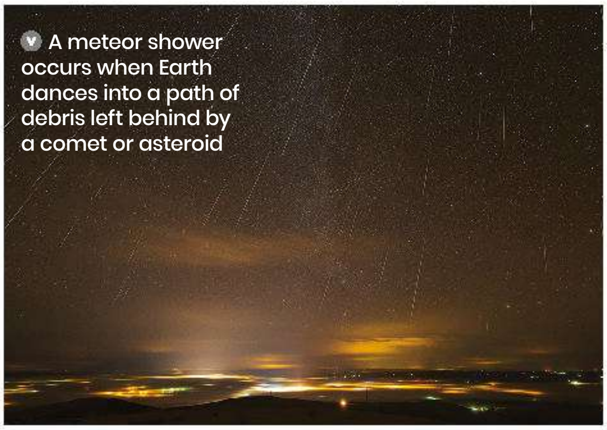
˅ An antennae array under a meteor-filled night sky

© Getty

Counting meteors is scientifically important. Differences in the speed, direction, brightness and colour of meteors can tell us a lot about the nature of the object that produced them. For example, Geminid meteors tend to move more slowly than meteors left by comets, and they burn up at a much lower altitude, about 38 kilometres (24 miles) above ground.

Occasionally, a meteor entering the atmosphere is a little larger than the rest. Rather than just leaving the thin streak of a shooting star, they are bigger and brighter, sometimes even brighter than Venus. These are fireballs that are burning up lower in the atmosphere. The brightest are called bolides – if you're lucky enough to see one, you might even see flaming chunks breaking off. Meteors around 20 to 30 metres (66 to 98 feet) in size will explosively fragment in the atmosphere, causing an airburst like the dramatic event that occurred over the Russian city of Chelyabinsk in 2013. This exploded 30 kilometres (18 miles) above the ground, and the shock wave shattered windows, damaged roofs and sent 1,500 people to hospital with cuts from flying glass.

The biggest meteors can actually reach the ground before they completely disintegrate. We call these meteorites, and over 60,000 of these have been found on Earth. Most are chunks of rock smaller than your hand, and the most common place to find them is in the white, icy landscape of Antarctica or a barren desert. Here the charred, black rocks stand out like a sore thumb. Not all meteorites come from asteroids – a handful come from the Moon and Mars.



A meteor shower occurs when Earth dances into a path of debris left behind by a comet or asteroid

NASA and the Japan Aerospace Exploration Agency (JAXA) have both launched asteroid sample-return missions, where a craft visits a celestial body and brings back material for examination on Earth. But meteorites are naturally occurring samples, bringing pieces of other celestial bodies to Earth. They're not pristine, having been blasted into space – probably as the result of an impact – before being burned in the atmosphere and landing on the ground on Earth. But they can tell us a great deal about the geology and chemistry of planets and asteroids. There has been speculation that some of the 277 meteorites from Mars contain evidence for life in the form of microbial fossils. This was a claim made by NASA scientists in the 1990s after examining a meteorite from Mars called ALH 84001, which was found in the Allan Hills region of Antarctica in 1984. Unfortunately, most scientists are now convinced that the microscopic features are not fossils at all, or if they are then they are fossils of microbes from Earth that contaminated the meteorite while it lay on the ice in Antarctica.

Meteorites can also tell scientists plenty about the dawn of the Solar System and the birth of Earth. This is because many meteorites represent debris left over from the distant era when the planets were forming 4.5 billion years ago. They are broadly split into three types: stony meteorites, iron meteorites and a mixture of the two. Stony meteorites, especially a specific type called chondrites, make up the vast majority of meteorites and are the same type of rock that built planets like Earth. They are very primitive, having never really melted, and so they preserve the chemical building blocks of the planet-forming disc that surrounded the young Sun.

The other type of stony meteorites are called achondrites, and these have melted – either in the impacts that blasted them off their original asteroid or when they were buried deep inside a large asteroid where conditions were hot. Achondrites are special because they tell us about the chemical conditions within large asteroids and the protoplanets similar to those that eventually became the true planets.

Iron meteorites also come from the cores of protoplanets, because that's where all the iron sank to when they formed. Iron meteorites are incredibly hard and dense,

ASTEROID TYPES

The differences between four main categories of these space rocks explained

253 Mathilde

C-type Carbonaceous

They're so dark due to their carbon-black surfaces that even the largest require a telescope to detect. They consist mostly of clay and silicate rocks and account for more than 75 per cent of all asteroids. Most of these ancient space rocks orbit in the outermost regions of the asteroid belt.

433 Eros

S-type Stony

This class of asteroids orbit the inner asteroid belt and are primarily composed of stony materials, metallic nickel-iron as well as iron and magnesium silicates. S-types are the second most common asteroids and are also among the brightest – some larger examples, such as 7 Iris, can be spotted with binoculars.

21 Lutetia

M-type Metallic

M-types are pure metal, or mixtures of metal and small amounts of stone, and have originated from the cores of planetary bodies that have been broken apart by impacts. Most are metallic, comprising largely of nickel-iron, and they are found in the middle region of the asteroid belt.

4 Vesta

V-type Vestoid

V-types have similar surface properties to 4 Vesta, one of the largest asteroids in the Solar System. They're not so different in composition to S-type, also made from stony iron and chondrites, but they contain higher levels of silicon-aluminium oxides called pyroxenes. They are a reddish colour.

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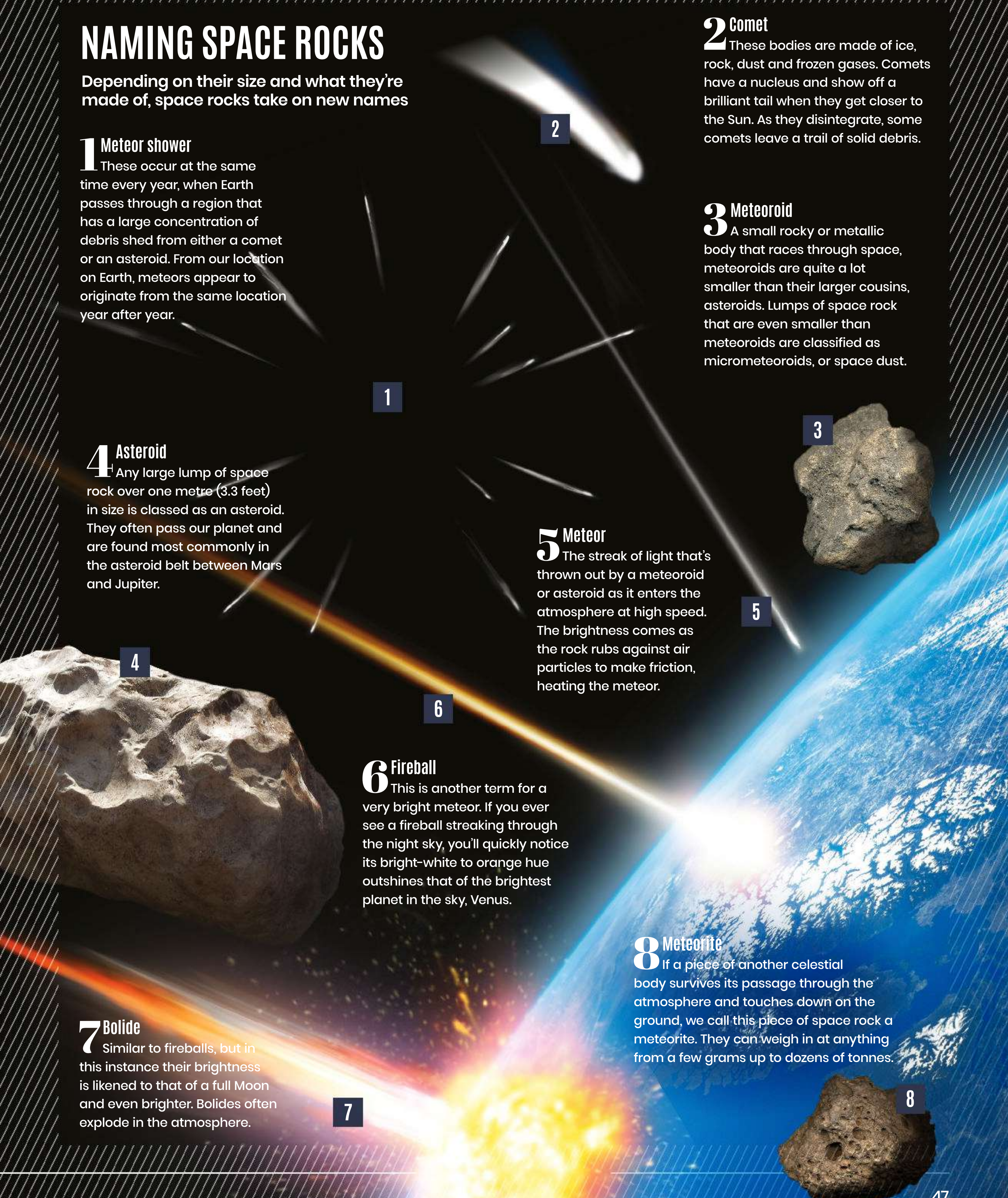
NAMING SPACE ROCKS

Depending on their size and what they're made of, space rocks take on new names



1 Meteor shower

These occur at the same time every year, when Earth passes through a region that has a large concentration of debris shed from either a comet or an asteroid. From our location on Earth, meteors appear to originate from the same location year after year.

2 Comet

These bodies are made of ice, rock, dust and frozen gases. Comets have a nucleus and show off a brilliant tail when they get closer to the Sun. As they disintegrate, some comets leave a trail of solid debris.

3 Meteoroid

A small rocky or metallic body that races through space, meteoroids are quite a lot smaller than their larger cousins, asteroids. Lumps of space rock that are even smaller than meteoroids are classified as micrometeoroids, or space dust.

4 Asteroid

Any large lump of space rock over one metre (3.3 feet) in size is classed as an asteroid. They often pass our planet and are found most commonly in the asteroid belt between Mars and Jupiter.

5 Meteor

The streak of light that's thrown out by a meteoroid or asteroid as it enters the atmosphere at high speed. The brightness comes as the rock rubs against air particles to make friction, heating the meteor.

6 Fireball

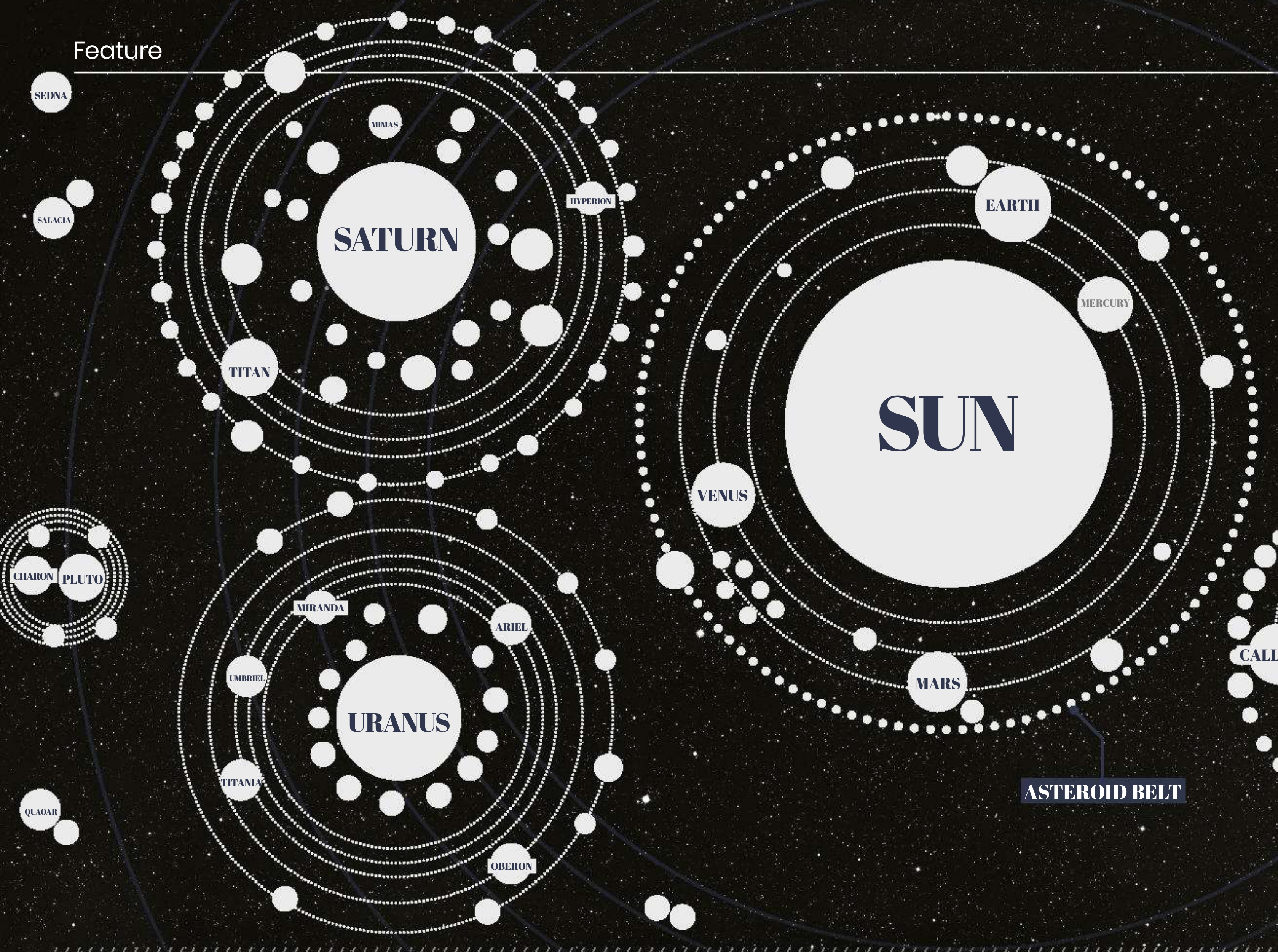
This is another term for a very bright meteor. If you ever see a fireball streaking through the night sky, you'll quickly notice its bright-white to orange hue outshines that of the brightest planet in the sky, Venus.

7 Bolide

Similar to fireballs, but in this instance their brightness is likened to that of a full Moon and even brighter. Bolides often explode in the atmosphere.

8 Meteorite

If a piece of another celestial body survives its passage through the atmosphere and touches down on the ground, we call this piece of space rock a meteorite. They can weigh in at anything from a few grams up to dozens of tonnes.



CELESTIAL BODIES

Discover some of the many dwarf planets and moons orbiting in our Solar System

Makemake

Found around 4.2 billion miles from the Sun, just outside the orbit of Neptune, this dwarf planet is the second-brightest object in the Kuiper Belt – the first being Pluto. Its discovery in 2005 prompted the International Astronomical Union to form a new classification of celestial bodies, called dwarf planets.

Haumea

Haumea sits in the Kuiper Belt and is one of the fastest rotating large objects in the Solar System. A single day on Haumea is equivalent to four hours on Earth, but due to its proximity to the Sun, one Haumean year is equal to 285 Earth years. This oval-shaped dwarf plane has two moons: Namaka and Hi’iaka.

Io

Io is one of the most volcanically active bodies in the Solar System. There are hundreds of volcanoes on the moon’s surface, each of them spewing lava dozens of miles high, along with lakes of molten silicate. It’s thought that Jupiter’s intense gravitational pull is the reason for Io’s explosive nature.

Callisto

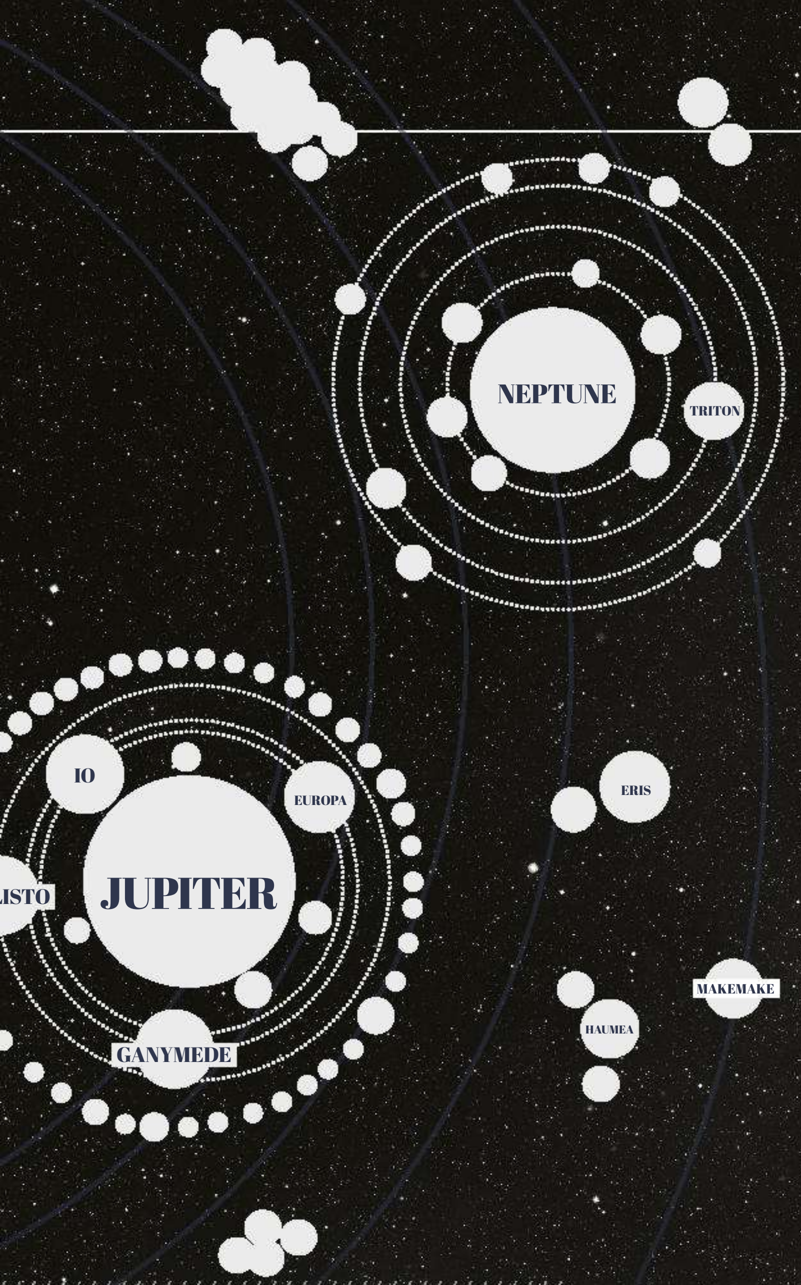
Callisto has a circumference of 9,410 miles, which is almost as big as Mercury. Not only is this moon impressively large, it has a salty secret deep below its icy surface. Discovered in 1610, it wasn’t until the 1990s that scientists proposed the moon has a subsurface ocean about 155 miles below its surface.

Europa

Another of Jupiter’s many moons, Europa is one of the oddest. With a surface temperature of around -160 degrees Celsius, this frozen satellite bears strange streaks. These markings are thought to be cracks in the moon’s icy surface, caused by the tidal forces of an ocean deep beneath it.

Titan

Although the structure of Titan remains unclear, scientists think its core is made of rock around 2,500 miles in diameter, surrounded by water ice. This satellite has a dense atmosphere, which gives it its yellow hue. The composition of this atmosphere is primarily nitrogen and some methane.



Mimas

Often called the Death Star moon for its similarity to the space station in Star Wars, Mimas is one of Saturn's smallest moons. Its iconic impact crater, named Herschel after English astronomer William Herschel, who discovered Mimas in 1789, spans 80 miles and reaches 3.5 miles high at its peak.

Hyperion

Not all moons are spherical. Some, like Saturn's sponge-like moon Hyperion, are irregular and filled with deep caverns. With a lower density than water, this moon is made up of water ice and frozen methane or carbon dioxide. Hyperion's appearance is thought to be the result of its distance from Saturn.

A Near-Earth objects are monitored by many organisations to prevent disaster

V Meteor showers are a truly stunning sight as pieces of comet dust burn up in the atmosphere

but only five per cent of all meteorites are of this variety. There are two types of stony-iron meteorites: pallasites and mesosiderites. Pallasites are recognisable thanks to their large crystals of a green mineral called olivine. Mesosiderites are more of a jumble of rock and metal, made when two asteroids collide in space, with the impact fusing different materials together.

On rare occasions, a really big meteor will enter Earth's atmosphere. These are sometimes big enough to blow out large craters or explode over towns and cities, causing harm. Over 100 years before the Chelyabinsk meteorite, a similar airburst flattened 80 million trees in Tunguska, a remote region in Siberia.

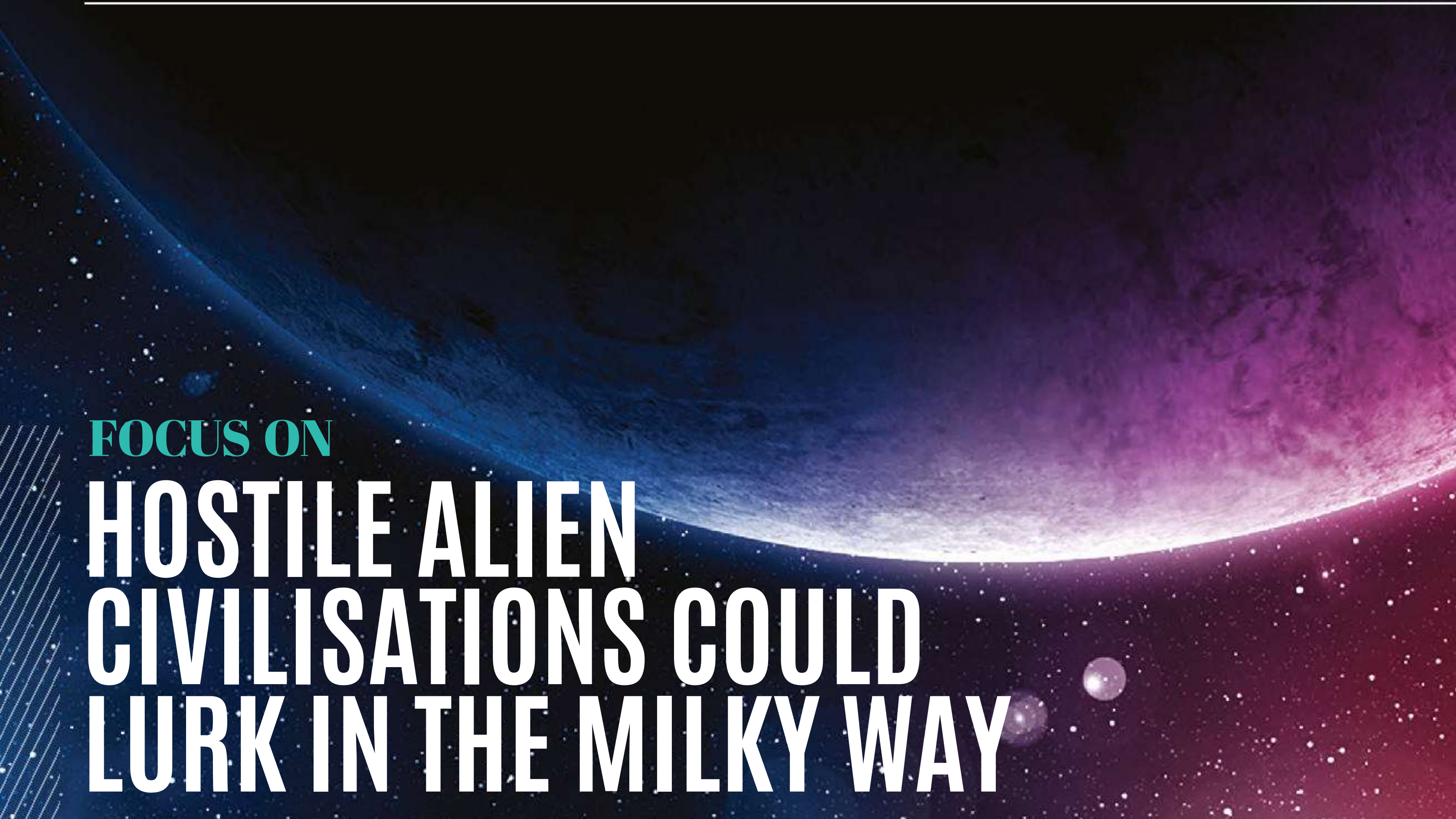
These events greatly worry scientists, who fear that one day an asteroid will hit us that could destroy a city or send so much dust into the air it would block out the Sun and end life on Earth. It's a big concern to Queen founder and astrophysicist Dr Brian May, who lends his support to the Asteroid Day event to raise awareness about this threat: "30 June was the anniversary of Tunguska in 1908. Not a huge object, but it exploded before it hit the ground, which flattened the trees for hundreds of miles around. Now that is a city destroyer – the force of a thousand atom bombs."

To forewarn us, NASA's Spaceguard program has found over 90 per cent of asteroids larger than a kilometre (0.62 miles) that come close to Earth. These are the real killers, like the asteroid that wiped out the dinosaurs 65 million years ago. However, there are still millions of undiscovered asteroids out there smaller than 100 metres (328 feet) that could still do serious damage.

Astroid-surveying missions remind us that we still have much to do to protect ourselves from asteroids. Comets can also be a danger, but because there are fewer of them they pose less of a risk. Instead Earth is more likely to fly through their tails so we can see spectacular meteor showers in the sky. From shooting stars to fireballs, meteors and meteorites, their origins are all the same, just on vastly different scales.

Colin Stuart
Science author and speaker
Colin holds a degree in astrophysics, has written over 17 books on space and has an asteroid named in his honour: 15347 Colinstuart.

© NASA/JPL; Getty



FOCUS ON

HOSTILE ALIEN CIVILISATIONS COULD LURK IN THE MILKY WAY

The probability of us being invaded was calculated based on recent human history and technological capabilities

Reported by Brandon Specktor

The Milky Way is home to millions of potentially habitable planets – and approximately four of them may harbour evil alien civilisations that would invade Earth if they could. A new paper, which has not yet been peer-reviewed, poses a peculiar question: what are the odds that humans could one day contact a hostile alien civilisation that's capable of invading our planet? To answer this, lead scientist Alberto Caballero, a doctoral student in conflict resolution at the University of Vigo in Spain, began by looking back at human history before looking out to the stars. "This paper attempts to provide an estimation of the prevalence of hostile extraterrestrial civilisations through an extrapolation of the probability that we, as the human civilisation, would attack or invade an inhabited exoplanet," Caballero wrote in the study. Caballero is not an astrophysicist, but he has published a study on the infamous Wow! Signal – a potential sign of extraterrestrial life – in the peer-reviewed *International Journal of Astrobiology*.

To reach his estimation, Caballero first counted the number of countries that invaded other countries between 1915 and 2022. He found that a total of 51 of the world's 195 nations had launched some sort of invasion during that period. Then he weighted each country's probability of launching an invasion based on that country's percentage of global military expenditure. From there, Caballero added each country's individual probability of instigating an invasion, then divided the sum by the total number of countries on Earth, ending up with what he describes as "the current human probability of invasion of an extraterrestrial civilisation." According to this model, the current odds of humans invading another inhabited planet are 0.028 per cent. However, Caballero wrote, that probability refers to the current state of human civilisation – and humans aren't currently capable of interstellar travel. If current rates of technological advancement hold, then interstellar travel

> "The current odds of humans invading another inhabited planet are 0.028 per cent"

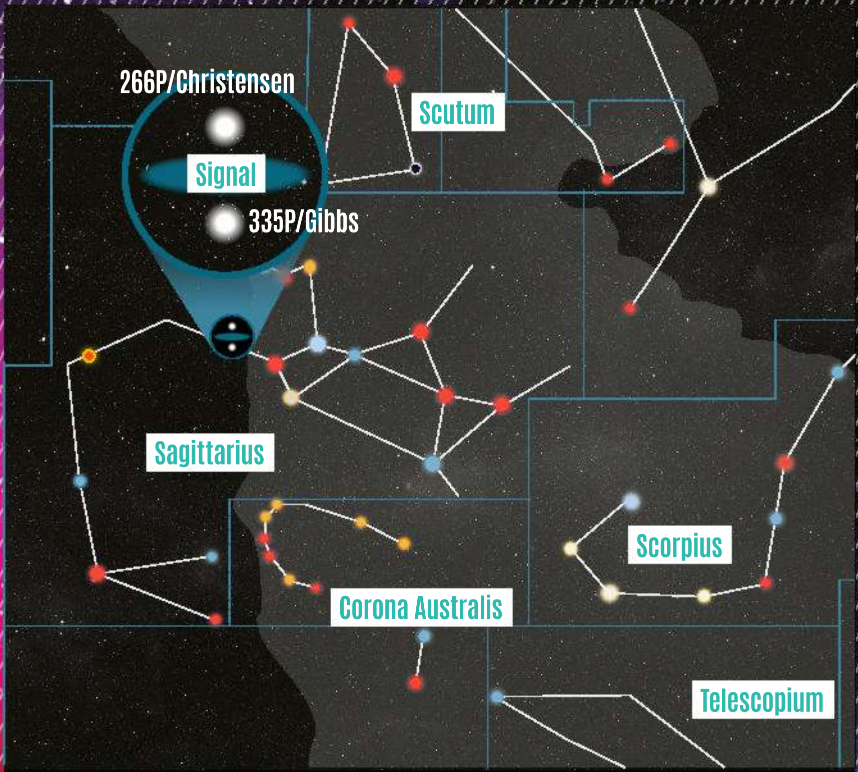
shouldn't be possible for another 259 years, Caballero calculated using the Kardashev scale – a system that categorises how advanced a civilisation is based on its energy expenditure.

Assuming the frequency of human invasions continues to decline over that time at the same rate that invasions have declined over the last 50 years – an average of -1.15 per cent per year, according to Caballero's paper – then the human race has a 0.0014 per cent probability of invading another planet when we potentially become an interstellar – or Type 1 – civilisation 259 years from now. That may sound like very slim odds, and it is until you start multiplying it by the millions of potentially habitable planets in the Milky Way. For his final calculation, Caballero turned to a 2012 paper published in the journal *Mathematical SETI*, in which researchers predicted that as many as 15,785 alien civilisations could theoretically share the galaxy with humans.

Caballero concluded that less than one of these Type 1 civilisations – 0.22, to be precise – would be hostile towards humans who make contact. However, the number of malicious neighbours increases to 4.42 when accounting for civilisations that, like modern humans, are not yet capable of interstellar travel, Caballero said. "I don't mention the 4.42 civilisations in my paper because we don't know whether all the civilisations in the galaxy are like us; a civilisation like us would probably not pose a threat to another one since we don't have the technology to travel to their planet," Caballero said.

Four hostile alien powers doesn't seem like a lot to worry about. Furthermore, the probability that humans might contact one of these malicious civilisations – and then be invaded by them – is vanishingly small, Caballero added. "The probability of extraterrestrial invasion by a civilisation whose planet we message is around two orders of magnitude lower than the probability of a planet-killer asteroid collision," he wrote in his paper, adding that planet-killing asteroids – like the one that doomed the dinosaurs – are 1-in-100-million-year events.

THE WOW! SIGNAL'S ORIGIN



Temperatures of the stars in Kelvin

● **O** Blue stars Over 30,000K

● **B** Blue-white stars 10,000 to 30,000K

● **A** White stars 7,500 to 10,000K

● **F** Yellow-white stars 6,000 to 7,500K

● **G** Yellow stars 5,200 to 6,000K

● **K** Orange stars 3,700 to 5,200K

● **M** Red stars 2,400 to 3,700K

● Other Cool red and brown dwarfs

○ UNKNOWN SPECTRAL CLASS

Though Caballero's study poses an interesting thought experiment, the author admits his model has limitations. The invasion probability is based on a very narrow slice of human history, and it makes many assumptions about the future development of our species. The model also presumes that alien intelligence will have brain compositions, values and senses of empathy similar to those of humans, which may simply not be the case, said Caballero. "I did the paper based only on life as we know it," he said. "We don't know the minds of extraterrestrials." And by the looks of things, it'll be at least a few hundred more years until we do.

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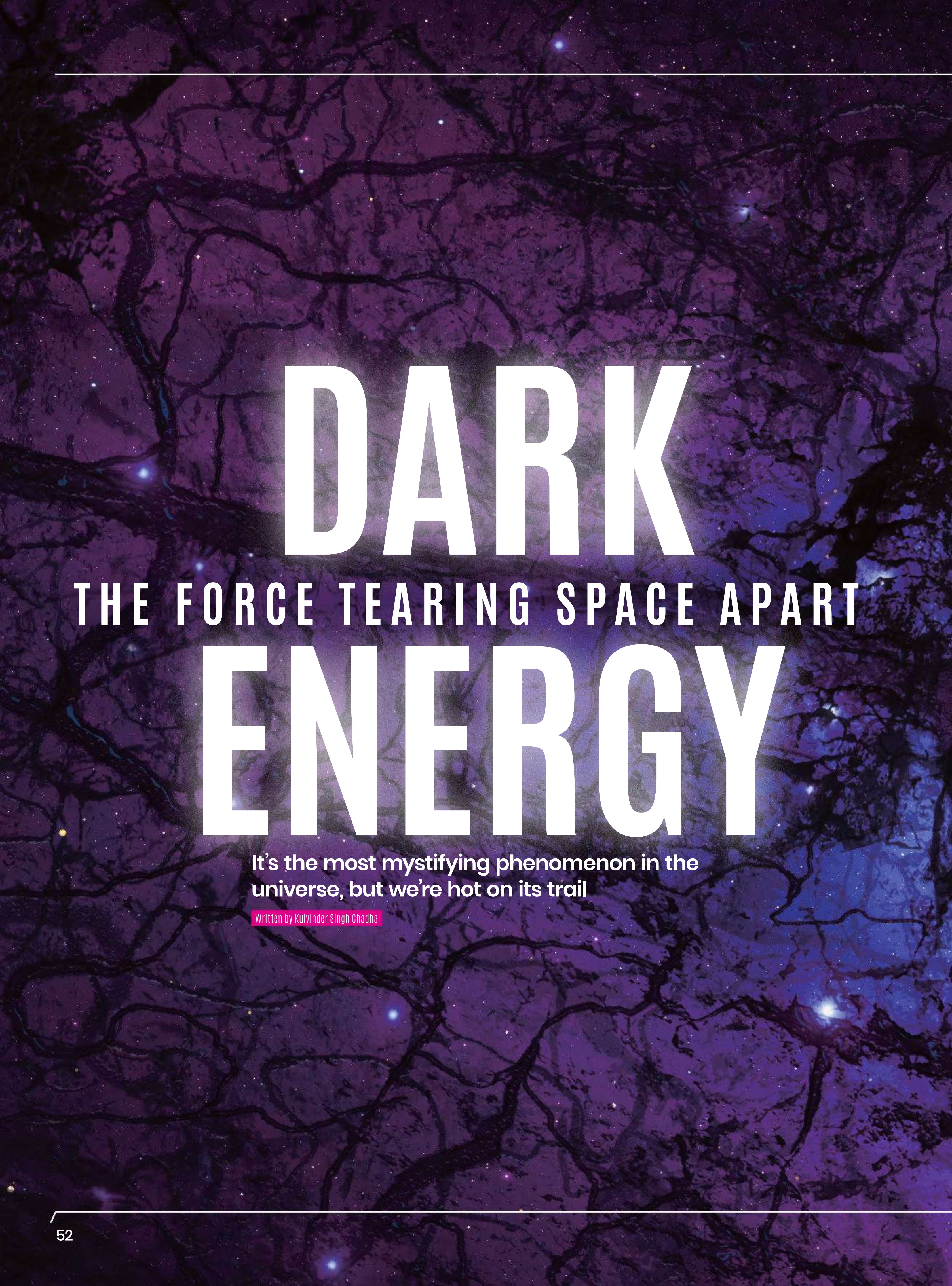

DARK ENERGY

THE FORCE TEARING SPACE APART

It's the most mystifying phenomenon in the universe, but we're hot on its trail

Written by Kulvinder Singh Chadha

Our universe is growing. Ever since the Big Bang, every point in the fabric of space has been expanding in all directions. This expansion is carrying almost all galaxies away from us. The biggest surprise came in 1998 with the discovery that not only is the universe expanding, but that expansion is accelerating. Nobody knows why, but scientists have come up with a term for the mysterious force driving the acceleration: dark energy.

According to data from the European Space Agency's (ESA) Planck spacecraft, dark energy constitutes over two-thirds of all the mass and energy in the universe, or 68.3 per cent. The remainder is 26.8 per cent dark matter and just 4.9 per cent normal matter, which makes up the stars, galaxies and planets. Scientists are perplexed as to what dark energy is. There are ideas, but nothing concrete. It's important to try and figure out the puzzle of dark energy because the fate of the universe depends on it. Prior to the discovery of dark energy, cosmologists had expected to find that the expansion of the universe was running out of steam 13.8 billion years after the Big Bang. If that was the case, the universe could have gone in three directions depending upon how much matter, and therefore gravity, there was in the universe.

If there was enough matter, its gravity would act on the expanding universe, slowing the expansion and gradually overcoming it, eventually causing the universe to begin to shrink again before collapsing in a 'Big Crunch'. If the amount of matter and gravity were finely balanced with the energy of the expanding universe, it would create a static universe that would remain forever. However, if there was not enough matter in the universe to counteract the expansion, then the universe would continue to expand forever, taking all the galaxies with it until they disappeared over the cosmic horizon, leaving the Milky Way all alone.

With the discovery of dark energy, the fate of the universe now seems much clearer. If dark energy keeps its strength and continues accelerating the universe's expansion, then it's more likely to expand forever. In the worst-case scenario, the expansion could be so extreme that it begins to tear galaxies, stars, planets and even atoms apart. However, since we don't know what dark energy is, we cannot predict what it is going to do in the future. Astronomers can measure what it is doing today and what it has done in the past, however, and are able to make some extrapolations based on that.

Dark energy was discovered by looking at the light of exploding stars in faraway galaxies. In particular, astronomers were looking at a breed of supernovae known as Type Ia. These are the explosions of white dwarf stars, and they tend to all explode with the same peak brightness. From our viewpoint, millions if not billions of light years away from these supernovae, they appear pretty faint. But because we know how bright they would be if we were up close to them, we can calculate how far away they are. Astronomers call these 'standard candles' and use them to measure distances across the universe. These distances are then compared to their cosmological redshift, which is the amount their light is stretched into redder wavelengths by the expansion of the universe.

It was the fact that the distances to these supernovae were greater than their redshift that implied that the expansion was getting faster, not slower, as identified by two teams of scientists: the Supernova Cosmology Project, led by Saul Perlmutter of Lawrence Berkeley National Laboratory, and the High-Z Supernova Search Team (Z is astronomy

An image of a galaxy cluster, with hot intracluster gas shown in pink. The blue overlay reveals the calculated areas of dark matter

WHAT IS DARK ENERGY?

All About Space asks the astrophysicists

"Dark energy makes up about 70 per cent of the universe. It seems to be evenly spread throughout. What we have discovered about dark energy is that it 'pushes', as in it repels outwards. It makes the entire universe – which is already expanding – expand faster."

Dr Karl Kruszelnicki
University of Sydney

"Dark energy is incredibly strange, but it makes sense that it went unnoticed. I have no clue what dark energy is. It appears strong enough to push the entire universe, yet its source is unknown, its location is unknown and its physics are highly speculative."

Dr Adam Riess
Johns Hopkins University

"It could pull the universe apart. If there's sufficient dark energy, the universe will at some point pull itself apart completely in a 'Big Rip'. The only problem is that we have no clue what dark energy is."

Dr Hitoshi Murayama
University of California, Berkeley

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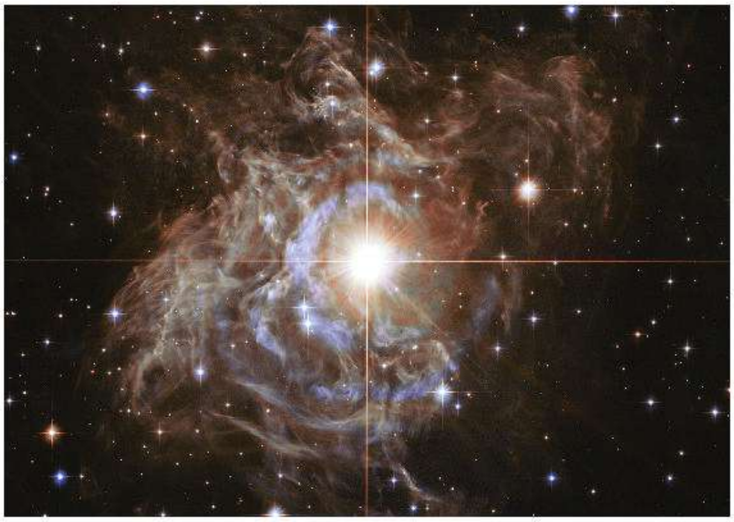

RS Puppis is an example of a Cepheid variable. These were essential in showing an expanding universe due to their luminosity-pulsation period relationship

The Dark Energy Survey, an international effort based at the Cerro Tololo Inter-American Observatory, Chile, began searching the southern skies on 31 August 2013

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shorthand for redshift) led by Harvard University's Brian Schmidt and Adam Riess of Johns Hopkins University.

Riess led a team of scientists who used Type Ia supernovae to discover that the expansion of the universe is even faster than previously thought. They searched for supernovae in galaxies in which they could also see a special type of variable star called Cepheid variables. These pulsating stars are also standard candles as their maximum luminosity depends on the length of their variation – the longer it takes for them to reach peak brightness and then fade back down to normal levels as they pulse, the brighter their peak will be.

Comparing the Cepheid data with the distance of those galaxies as measured by Type Ia supernovae, Riess' team was able to calibrate the supernova distance markers, allowing them to more accurately measure the distances to even more remote galaxies. While the Planck spacecraft had measured the expansion rate of the universe as being 66.5 kilometres (41.3 miles) per second per megaparsec – equal to 3.26 million light years – Riess' team found that actually the universe was expanding much faster, at 73.2 kilometres (45.5 miles) per second per megaparsec. That doesn't mean that Planck made a mistake. The rate of expansion that it measured – known as the Hubble constant – was from the very beginning of the universe, observed in the light of the cosmic microwave background (CMB) radiation just 380,000 years after the Big Bang.

On the other hand, Riess' team measured the Hubble constant in the modern universe. It isn't clear why the two values are different, but one explanation could be that dark energy has grown stronger over the years, speeding up the expansion, meaning that the Hubble constant isn't actually constant at all. If that's true, it has serious implications for the fate of the universe.

> **"We may not have the right understanding, and it changes how big the Hubble constant should be today" Adam Riess**

"If we know the initial amounts of stuff in the universe, such as dark energy and dark matter, and we have the physics correct, then you can go from a measurement at the time shortly after the Big Bang and use that to predict how fast the universe should be expanding today," says Riess. "However, if this discrepancy holds up it appears we may not have the right understanding, and it changes how big the Hubble constant should be today." Riess' findings also somewhat contradict another dark energy discovery made by scientists who used NASA's Chandra X-ray Observatory to observe galaxy clusters. Because galaxy clusters are filled with gas as hot as 1 million degrees Celsius (1.8 million degrees Fahrenheit) or more, they glow brightly in X-rays. These X-ray-emitting regions of galaxy clusters all have similar shapes and sizes relative to the size of the clusters themselves.

"In this sense, galaxy clusters are like Russian dolls, with smaller ones having a similar shape to the larger ones," says Andrea Morandi of the University of Alabama in Huntsville, who led the team. "Knowing this lets us compare them and accurately determine their distances across billions of light years." From these distances, the true size of the clusters can be gauged. Because the growth of galaxy clusters is ultimately stunted by dark energy pulling away galaxies that would otherwise join the clusters, how big galaxy clusters can reach during different epochs of history is an indication of how strong dark energy is and how it has acted over billions of years. Since a galaxy cluster's X-ray profile is a proxy for its true physical size, by measuring them with Chandra, Morandi's team found that dark energy doesn't seem to have become stronger or weaker in the last 8.7 billion years. This might mean that a

DARK ENERGY VS DARK MATTER

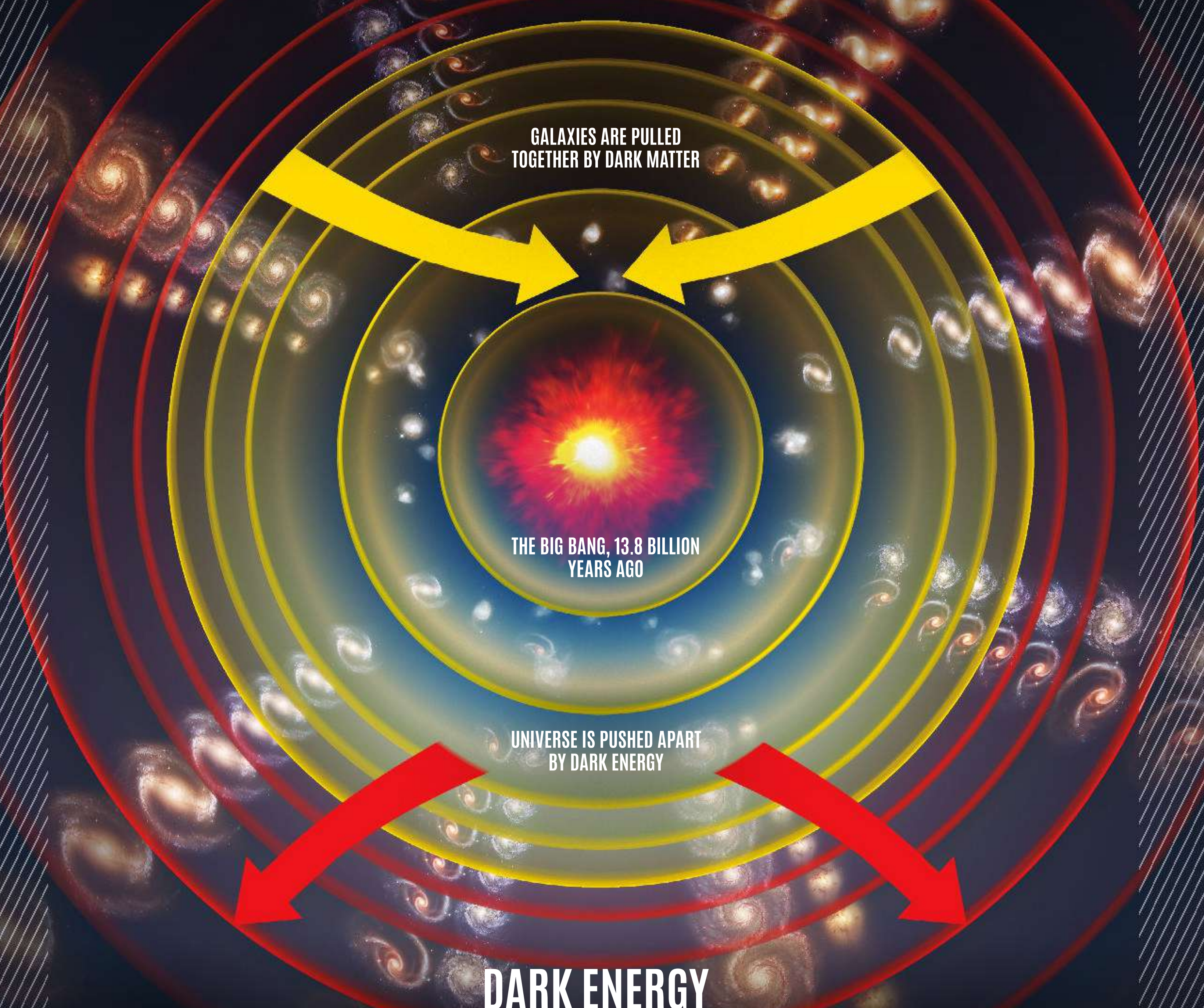
DARK MATTER

It's entirely invisible and neither emits or absorbs heat, light or radiation of any kind.

It can be detected indirectly by its gravitational effect on normal matter and space-time.

It comprises 84.54 per cent of all matter in the universe, or 26.8 per cent of the universe's total make-up.

It plays a crucial role in galaxy formation and stops galaxies from flying apart.


GALAXIES ARE PULLED TOGETHER BY DARK MATTER
THE BIG BANG, 13.8 BILLION YEARS AGO
UNIVERSE IS PUSHED APART BY DARK ENERGY

DARK ENERGY

It's accelerating the expansion of space, shown by studies of supernovae in distant galaxies.

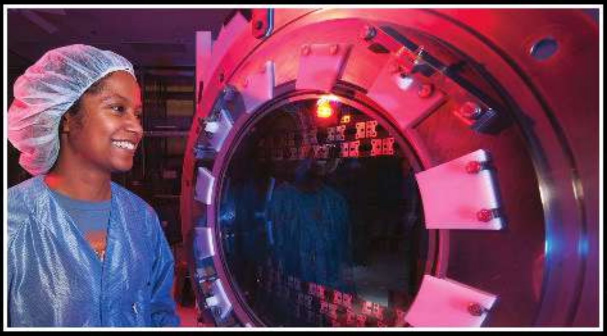
It exerts a small negative pressure that's constant throughout space and acts against gravity.

It affects the shape of the universe and its large-scale structure, such as how galaxies are spread out.

It was first discovered by astronomers in the late 1990s.

DARK ENERGY MAPPERS

A new generation of instruments promises to hunt down dark energy, exposing its secrets

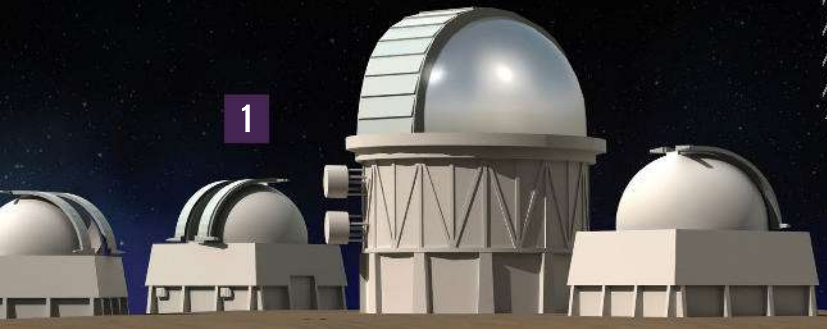


1 Dark Energy Survey

This was a visible and near-infrared survey of the universe using the four-metre (13-foot) Blanco Telescope at the Cerro Tololo Inter-American Observatory in Chile. The telescope was fitted with the state-of-the-art robotic Dark Energy Camera (DECam), which surveyed 300 million extremely faint galaxies and thousands of supernovae over an eighth of the total sky. The DECam instrument made repeated observations of certain areas of the sky in various wavelengths, as well as more long-period observations to pick out the faintest galaxies. The project's results hope to discover if dark energy's density changes over time.

2 Square Kilometre Array

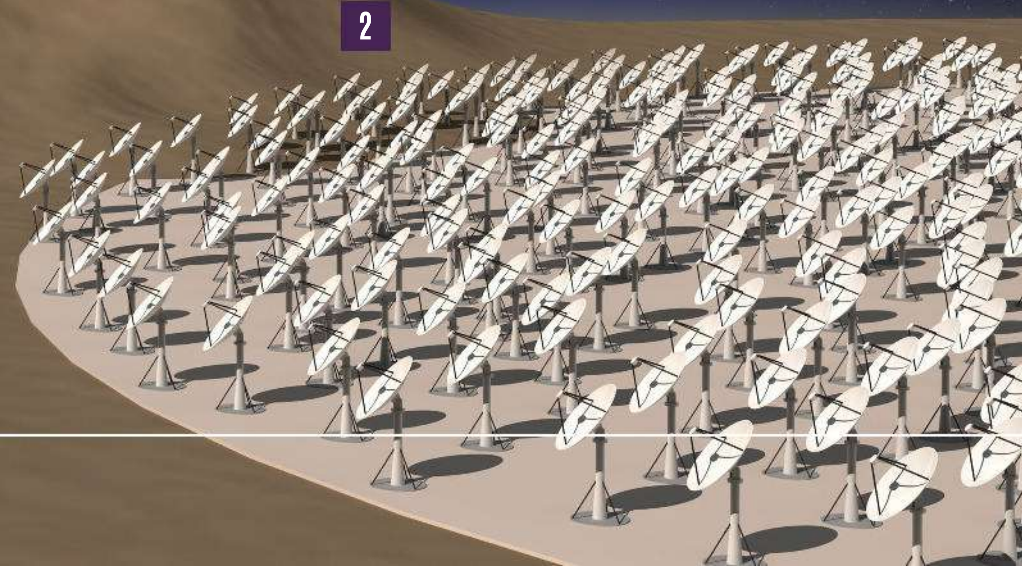
The Square Kilometre Array (SKA) will span two continents when it begins operation in 2027. As the largest radio telescope network in history, all of the SKA's individual elements will be able to act like a single super-continental radio dish, giving it the ability to study the universe in resolutions never before seen in radio wavelengths. In particular, emissions from hydrogen gas – the most abundant element in space – will be mapped in three dimensions from the distant past to the present day. The SKA's high resolving power could reveal dark energy's effects from ripples in the gas and more information on galactic evolution.



> "Galaxy clusters are like Russian dolls, with smaller ones having a similar shape to the larger ones"
>
> **Andrea Morandi**

3 Euclid space telescope

How has dark energy contributed to the universe's acceleration over cosmic time? This is what the Euclid spacecraft will try to ascertain when it's launched in 2023. It will do this by measuring the redshifts of galaxies back to when the universe was just 28 per cent of its current age. It will also look at gravitational weak lensing as well as ripples in normal matter – usually in hydrogen gas between galaxies. To get decent results, Euclid will survey at least half the entire sky with its visible and near-infrared cameras.



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change in the expansion rate of the universe occurred before then, closer to the time of the Big Bang.

Galaxies can also reveal the presence of dark energy in other ways. We've seen standard candles in the form of supernovae, so now meet 'standard rulers', physical yardsticks that we can measure dark energy against. The distribution of galaxies in the universe can be traced back to perturbations seen in the cosmic microwave background, which resulted in a standard distance between galaxies. This standard distance can act like a ruler, and by measuring how the distance between galaxies has grown as the universe has expanded, astronomers can measure the strength of dark energy.

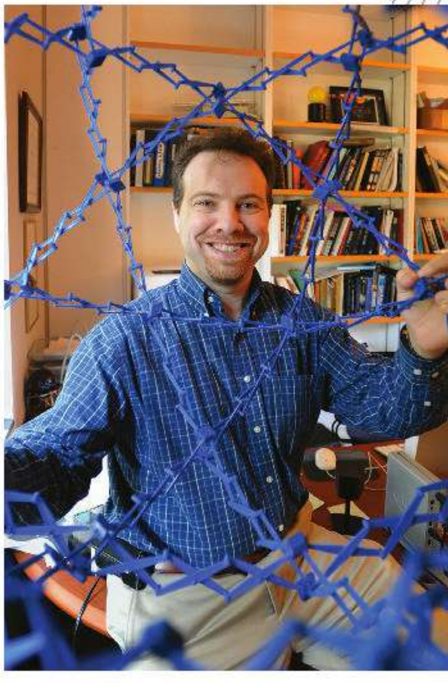
However, for standard candles and standard rulers to really make a difference in our quest to solve the mystery of dark energy, what scientists really need is more data. This data will come from giant galaxy surveys conducted by both general-purpose observatories and dedicated dark energy projects. First up was the Dark Energy Survey, an international project to detect many thousands of Type Ia supernovae which also aimed to map out the large-scale structure of the universe in the form of hundreds of millions of galaxies, providing many more examples of standard rulers. The Dark Energy Survey made observations from 2013 to 2019 using the four-metre (13-foot) Víctor M. Blanco Telescope and its powerful 570-megapixel Dark Energy Camera at the Cerro Tololo Inter-American Observatory, situated in Chile. The project released its first batch of data for scientists to begin analysing in January 2016, and so far three years of observation data have been released.

"Thanks to the extreme sensitivity of the camera and to the large area of sky that can be imaged through the telescope at once – 15 times the size of the full Moon – we expect the Dark Energy Survey to find more supernovae than any previous experiment," comments Dr Chris D'Andrea of the University of Portsmouth. In the first few months alone, it found 200 Type Ia supernovae. However, we're still a few years away from having a thorough analysis of the results.

There's also the Dark Energy Spectroscopic Instrument, or DESI for short, at the four-metre (13-foot) Nicholas U. Mayall Telescope at Kitt Peak National Observatory in Arizona. It will measure the cosmological redshifts of 30 million galaxies out to a distance of 10 billion light years in order to create a huge map of the large-scale structure in the universe. It will look at how the expansion of the universe has stretched the space between individual galaxies, as well as the size of galaxy clusters. It saw first light in 2019, just as the Dark Energy Survey completed its work, so we will have to wait a while for its results. It will build on the efforts of previous surveys such as BOSS, the Baryon Oscillation Spectroscopic Survey, which was part of the Sloan Digital Sky Survey based in New Mexico. This measured the redshifts of a million galaxies across 6 billion light years and allowed comparisons to be made of the growth of standard rulers between the modern day and 6 billion years ago.

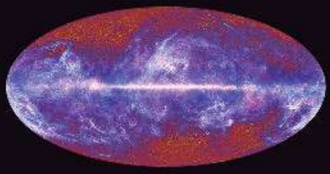
It's an even longer time frame for other projects. The most powerful digital camera in the world, featuring 3.2 billion pixels, has been fitted to the heart of the Vera C. Rubin Observatory – a huge 8.4-metre (27.6-foot) telescope that recently finished construction on a mountain called Cerro Pachón in Chile. While it will be a general-purpose survey telescope, its Legacy Survey of Space and Time (LSST) will map millions of

▲ An extraordinary example of gravitational lensing in galaxy cluster Abell 2218 due to dark matter. There's not enough visible matter to distort the light from background galaxies



▼ Riess and his High-Z Supernova Team published some of the first evidence that the expansion of the universe is accelerating

EVIDENCE FOR DARK ENERGY

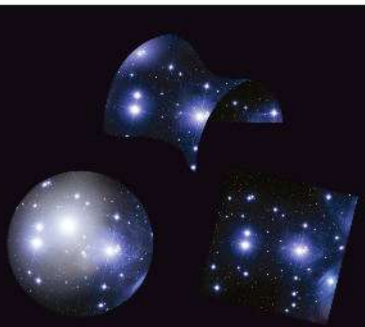


Relic radiation

The CMB is the primordial 'echo' of the universe. Measurements taken by probes show that the universe's geometry is nearly flat. For that to be the case, the total amount of matter in space must tally with the average density of matter to energy in the cosmos. But the CMB's spectrum shows that this isn't what's happening – matter only accounts for 30 per cent of the density.

Exploding stars

Type Ia supernovae occur in binary systems when a white dwarf's gravity pulls material from the other star onto itself, causing it to explode, briefly outshining all other stars in its galaxy. Their intrinsic brightness is known, so their distances can be calculated from how dim they appear. Using this, scientists were able to show that the universe's expansion is accelerating.



The shape of the cosmos

Its shape is governed by the general theory of relativity, which describes how space-time is warped by matter. Measurements of the CMB show that the universe is nearly flat, but there's not enough matter to keep it that way. Since $E=mc^2$ shows that matter and energy are two sides of the same coin, could dark energy remedy the shortfall?

The universe is expanding

The expansion rate of the universe is the time it takes to expand a certain amount. In a certain period of time, space will expand by a certain amount – whatever makes space expand doesn't dilute or decrease in density. An expanding universe leads to a greater amount of space, and more of what caused the expansion. This suggests dark energy may be a feature of space itself.

galaxies and find many more supernovae to aid in the quest to learn more about dark energy.

But there are more ways to study dark energy than just with visible light. The Square Kilometre Array, a vast interconnected network of thousands of small radio telescopes that will come online in the next decade, will study dark energy in two ways. First, it will listen for how the gravity of galaxy clusters affects the passage of radio waves through the universe, with the size of the radio distortion being a signal to indicate the different sizes of standard rulers across billions of years. It will also complete a survey of galaxies via the 21-centimetre (8.3-inch) wavelength radio emissions from neutral hydrogen in those galaxies, adding to the many galaxies observed by other surveys to help create a comprehensive map of the universe from which we will be able to measure dark energy across space and time.

Finally, the quest for dark energy will be heading into space with the joint ESA and NASA Euclid mission, set to launch in 2023. Armed with a 1.2-metre (3.9-foot) telescope – a decent size for a space mission – and a 600-megapixel digital camera, it will map the size and location of a whopping 2 billion galaxies, more than have ever been mapped before, across 10 billion light years. It will tell the story of the evolution of the standard rulers in the universe as well as highlight the result of the battles between gravity and dark energy in the growth of galaxy clusters.

"Euclid will provide a wealth of data on the three-dimensional matter distribution in the universe," says Ralf Bender of the Max Planck Institute for Extraterrestrial Physics in Germany, who is a scientist working on the Euclid mission. "Not only will this give us interesting insights into the evolution of galaxies and galaxy clusters, but we will also be able to better understand the accelerating expansion of the universe. Hopefully this will bring us a big step forward in solving the riddle that is dark energy."

Kulvinder Singh Chadha
Space science writer
Kulvinder is a freelance science writer, outreach worker and former assistant editor of *Astronomy Now*. He holds a degree in astrophysics.

Artist's impression of all four elements of the Square Kilometre Array dishes at night

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FOCUS ON

STRATOLAUNCH REVEALS ITS FIRST HYPERSONIC DESIGN FOR HIGH-ALTITUDE FLIGHTS

The Talon-A test vehicle will drop from the biggest plane ever built

Reported by Elizabeth Howell

The Talon-A will launch from Stratolaunch's carrier aircraft

URSA MAJOR TECH

Fresh off its fifth flight of the biggest plane ever built, Stratolaunch is readying to test a hypersonic vehicle that will launch from the huge Roc carrier aircraft. The Mojave-based company has said that it has structurally completed the Talon-A test vehicle, known as TA-0. A future flight will release TA-0, which is unpowered, to assess Roc's systems. "After completing TA-0 separation testing, the company will transition to flying its first hypersonic test vehicle, TA-1," Stratolaunch stated. "The team has also started fabrication of a third vehicle, TA-2, the first fully reusable hypersonic test vehicle."

Stratolaunch was going to do the first drop tests with Roc and Talon-A in early 2022, but will likely achieve full operational capability by mid-to-late 2023. TA-0 should do a captive carry flight later this year, meaning the vehicle will be tested underneath Roc to see how the test article affects the flight dynamics of the 117-metre (385-foot) carrier aircraft. Drop tests will occur with later generations of Talon-A at some undisclosed date.

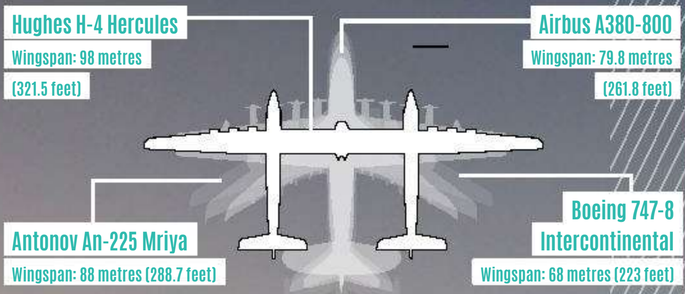
Stratolaunch was originally envisioned as a midair satellite launcher. Established in 2011 by Microsoft cofounder Paul Allen, the first test flight took place in April 2019, six months after Allen died. A few months later, in October 2019, a new set of owners bought the company with a fresh iteration of sending hypersonic vehicles aloft. These sorts of vehicles travel at least five times the speed of sound and have lately been the focus of numerous military programs in the US amid reports that Russia and China are focusing their developments on these high-speed systems.

In May, the Defense Advanced Research Projects Agency's Glide Breaker hypersonic missile interceptor program announced a second phase "to conduct wind tunnel and flight testing of jet interaction effects". The agency also recently announced that a Lockheed Martin hypersonic missile prototype flew at five times the speed of sound "for an extended period" as part of a separate program, the Hypersonic Air-breathing Weapon Concept (HAWC). And Raytheon Technologies completed a HAWC test of its own in September 2021.

Roc aced its fifth flight from Mojave Air and Space Port on 4 May. The Talon hypersonic vehicles will use a pylon that just flew for the first time on that fifth test flight. The 3,600-kilogram pylon includes a winch "that will load Talon-A vehicles onto the platform from the ground, expediting launch preparation and reducing the need for ground support," Stratolaunch stated. The hope is that the hypersonic test program will allow for outcomes such as technology development, science research or demonstrating key components for high-speed work.

STRATOLAUNCH: A GIANT IN THE SKY

With a wingspan greater than the length of a football field at 117 metres (385 feet), the Stratolaunch carrier aircraft dwarfs not just aircraft of the past, but also jets that can be found at airports today, making it the largest aeroplane that's ever taken to the skies. Longer than the Saturn V rockets that propelled NASA's Apollo Moon missions and the Skylab space station, the carrier aircraft weighs in at around 600,000 kilograms, including the fully fuelled launch vehicle.



© Stratolaunch

MYSTERIES OF THE UNIVERSE

WHY IS THERE A DWARF PLANET IN THE ASTEROID BELT?

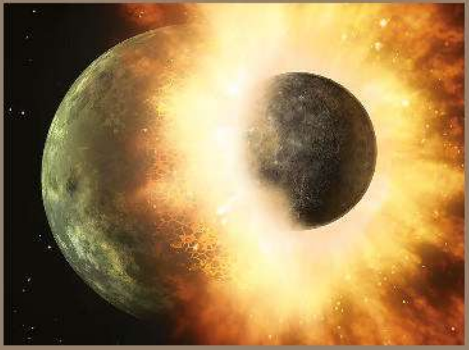
Ceres is rich in ammonia, but it should have evaporated in the early days of the Solar System's formation. Does that mean this tiny world is an intruder?

Reported by David Crookes

There's something special about Ceres, the small but significant world located in the asteroid belt between Mars and Jupiter. Quite aside from it potentially having a water-vapour plume and subsurface water, it's also a round object in an area otherwise filled with misshapen space rocks. It's much larger than any of its neighbours, and there's a slim chance it could harbour life. Ceres has also suffered an identity crisis. Originally deemed a planet after being discovered by Giuseppe Piazzi in 1801, it was later classified as an asteroid – the first to spotted. Since 2006 it's considered to be a dwarf planet, putting it on the same pedestal as Pluto. Yet just because it's special doesn't necessarily mean it belongs. In fact, some scientists think it's an intruder.

There's a clear reason. Ceres – which has approximately one-third of the total mass of the asteroid belt – is more hydrated than the asteroids in the same region. Crucially, explains Professor Ernesto Vieira Neto of São Paulo State University in Brazil, "it contains ammonia compounds" that its neighbours do not. This became abundantly clear after NASA's Dawn mission began orbiting the dwarf planet in 2015. The spacecraft discovered water and ammonia were reacting with silicate rocks. Some scientists suggested it may have been brought to Ceres by asteroids and meteorites. The trouble is, the ammonia isn't just on the surface – it's actually inside as well. This proved puzzling because ammonia is not generally found in this part of the Solar System.

Ammonia is more common in the frigid outer Solar System, so it begs the question how Ceres has an abundance of it in its current location. "Ammonia evaporates at much lower temperatures than water," says Vieira Neto. "This suggests that in order for a body to have ammonia in its composition, it needs to be far from the Sun. Ceres has ammonia inside it, which means it couldn't have formed in the region it is now." In other words, Ceres is likely to have formed somewhere else – farther from the Sun than it is today – and somehow found its way into the asteroid belt at an early stage in its life. "It's not that ammonia is more abundant in the outer Solar System but that it condenses in that region and facilitates its incorporation into the planetesimal formation



The early Solar System was a violent place, and it took a while for the planets and other bodies to form the order we observe today

© NASA; Getty

process," Vieira Neto continues. What's more, it's a theory that has been around for some time.

"There was already speculation that there was ammonia on Ceres, but it was not possible to have a good estimate with the measurements made by the telescopes we have," Vieira Neto explains. "Dawn orbited Ceres, and the measurements obtained were able to characterise the existence of ammonia." Indeed, in 2008, even before Dawn visited Ceres, William B. McKinnon, a planetary geologist at Washington University in St Louis, suggested that Ceres could be a refugee from the Kuiper Belt.

Later, in 2015, planetary scientist Carle Pieters from Brown University, a co-investigator on the Dawn mission, analysed the bulk composition of Ceres' surface and found it to be covered in ammonia-rich clays, affirming McKinnon's hypothesis. Pieters also raised the possibility that Ceres formed en masse further out. She said that small pebbles of ammoniated material may have swept in from farther out in the Solar System during the early phases of accretion. More and more, however, scientists followed the intruder line of inquiry. In the same year, Simone Marchi, a senior research scientist at the Southwest Research Institute in Boulder, Colorado, also suggested Ceres could have been formed farther

THREE POTENTIAL EXPLANATIONS

Scientists have come up with numerous theories for why Ceres has lots of ammonia on its surface

Ceres formed in the asteroid belt

Maybe Ceres really is an oddball, forming in the asteroid belt and accumulating ammonia in a way that differentiated it from other neighbouring asteroids. But if so, why did the Sun not vaporise the ammonia?

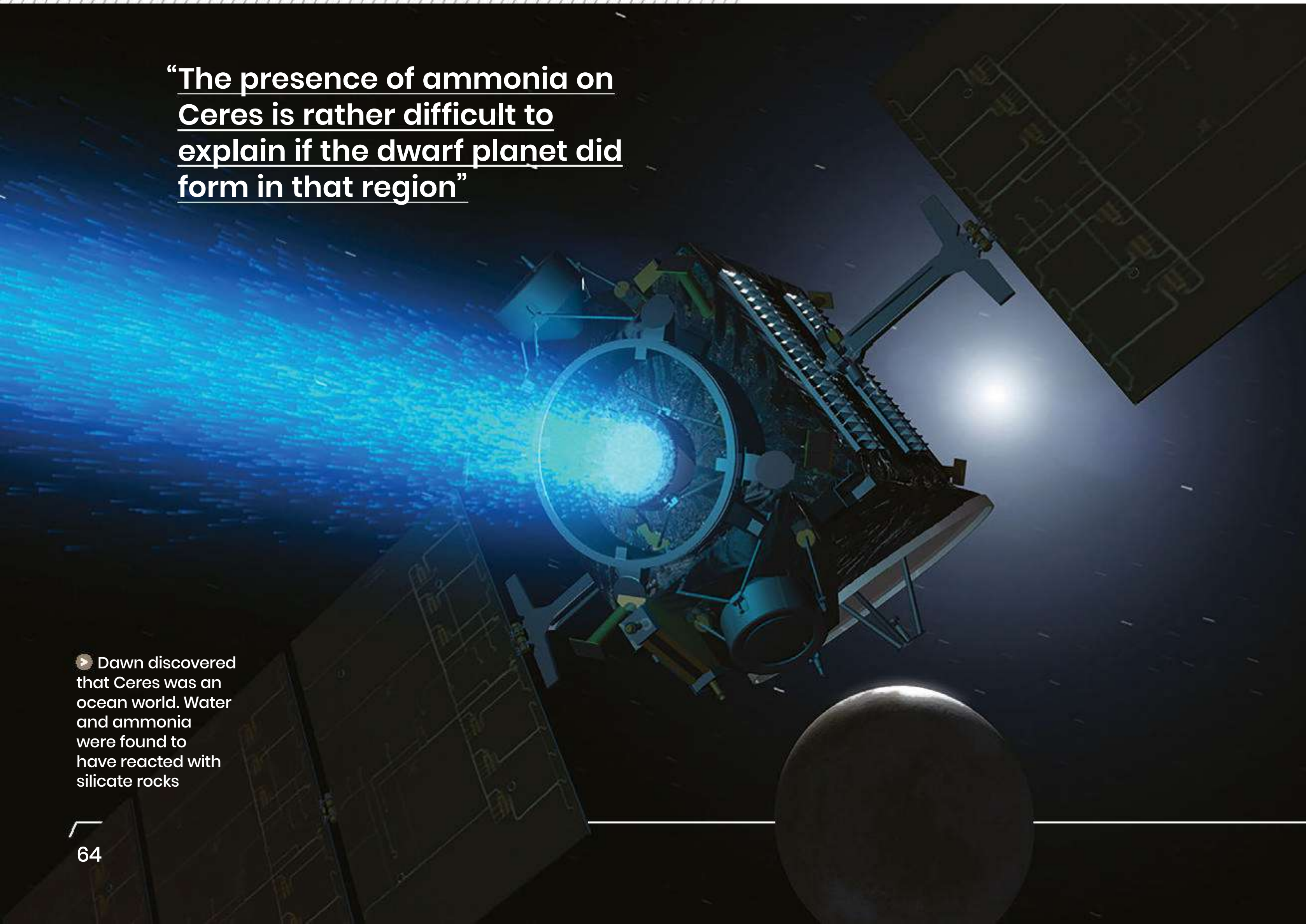
Ammonia came from afar

It's possible that materials from the outer Solar System found their way to Ceres over millions of years, bringing the ammonia to it. Somehow this activity would have centred on Ceres and bypassed the other objects in the asteroid belt.

Ceres moved in from elsewhere

The prevailing theory is that the dwarf planet formed in an orbit beyond Saturn, where ammonia could survive. It may have been one of thousands pulled in by Jupiter's massive gravity, causing it to end up in orbit in the asteroid belt.

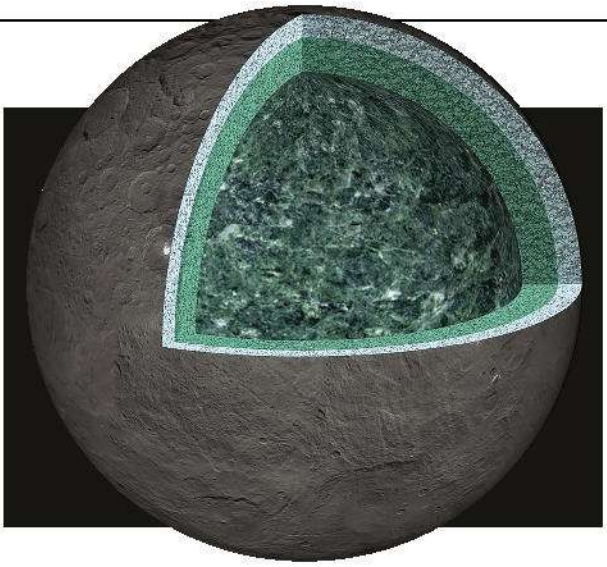
> "The presence of ammonia on Ceres is rather difficult to explain if the dwarf planet did form in that region"



Dawn discovered that Ceres was an ocean world. Water and ammonia were found to have reacted with silicate rocks out. Mike Brown, the California Institute of Technology astronomer who had a part in Pluto's planetary downgrade to dwarf status, says there's a good chance Ceres, which has a similar density to Pluto, could have formed elsewhere.

With all that in mind, Vieira Neto has been trying to get to the bottom of what may have happened to Ceres 4.5 billion years ago. He has been working with study lead Rafael Ribeiro de Sousa, also at São Paulo State University, as well as other scientists in Brazil, France and the US, on a plan to explain why Ceres is the oddball among the asteroids. The scientists sought to work out where Ceres most likely originated, and if it did appear to have come from the outer Solar System, how it may have ended up travelling inwards to its current location. In doing so, they're effectively ruling out the suggestion that Ceres formed in the asteroid belt, perhaps as a result of any collisions of the space rocks there.

If nothing else, the presence of ammonia on Ceres is rather difficult to explain if the dwarf planet did form in that region. If Ceres emerged in its current location and ammonia was shipped to its surface from far-flung bodies passing by and colliding, why would there not be any ammonia on other objects in the asteroid belt – a case of Ceres being too big to miss or just pure luck? There's something else to consider. "Ceres may have spent about 4.5 billion years in the asteroid belt, but due to the Sun's irradiation, all of the ammonia on the surface should have evaporated," Vieira Neto says. "The likely explanation for why Ceres continues to have ammonia is that it has it inside. Since the region where Ceres is currently located cannot condense ammonia in a way that it can be incorporated into its interior, it's possible that this has occurred in the outer Solar System."



Dawn data points towards Ceres having a mantle of hydrated clays covered by a layer of hydrated minerals, salts and ice

Another explanation is important if we're to understand Ceres better. "Given that Ceres may have formed in a more distant region of the Solar System, we needed a mechanism to bring it closer to the Sun," Vieira Neto explains. "What we did in our

Ceres is also geologically alive, with evidence of dozens of ancient volcanoes on its surface

CERES BY NUMBERS

1801	Year it was discovered
2006	Year it was classified as a dwarf planet
587	Diameter of Ceres in miles
-38°	Highest surface temperature in degrees Celsius
14	times less massive than Pluto
2.8	Astronomical units away from the Sun
22	Minutes taken for sunlight to travel to Ceres
3%	Ceres has a surface gravity that's three per cent of Earth's
1,682	Earth days taken to make a trip around the Sun
SIX	Kilograms of mass lost in steam every second

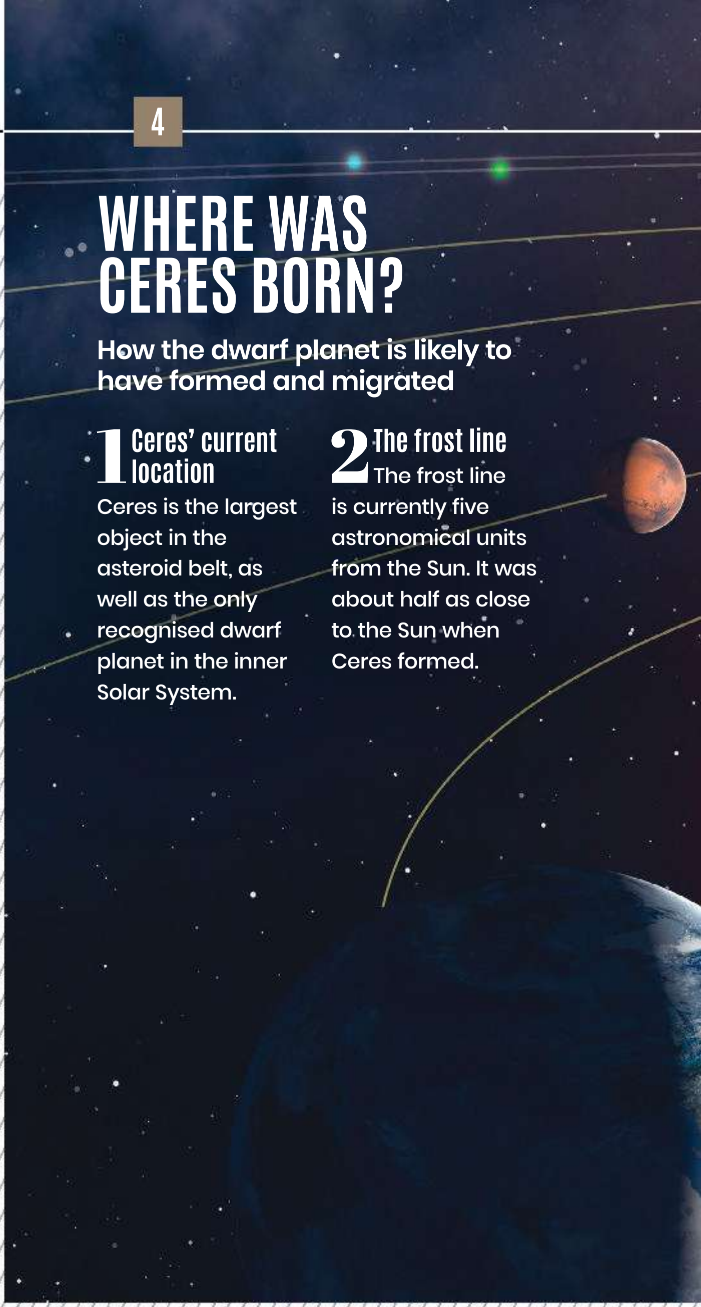
© NASA

work was test mechanisms such as gas drag from the formation of the Solar System and near collisions with embryos from the planets Uranus and Neptune through numerical integrations." The scientists came up with a scenario that put Jupiter at the centre, proposing that Ceres formed in the colder region well beyond Saturn's orbit where there is an abundance of ammonia. The huge gravitational instability caused by the formation of Jupiter and Saturn is then thought to have thrust the dwarf planet into the asteroid belt.

A computer simulation was created to test the hypothesis, based on the assumption that Ceres was a planetesimal – building blocks of planets, asteroids and comets. According to the paper published in the journal *Icarus*, they modelled the protoplanetary disc – the rotating disc of dense gas and dust which surrounded the Sun – so that it contained Jupiter, Saturn, the precursors of Uranus and Neptune as well as a number of Ceres-sized objects containing a similar chemical composition. The simulation showed that the precursors of Uranus and Neptune violently collided and that planets some three times more massive than Earth found themselves entering the inner Solar System. Around 3,600 objects of a similar size to Ceres were also being scattered – a number based on previous estimates by other research groups. All of these events assume that Jupiter is the big disrupter – a role for the gas giant proposed in many other studies.

"Jupiter's role in the simulations has two main effects: the formation of the ice giants, which causes the scattering of Ceres-like planetesimals, and the generation of resonances that will protect the captured object from gas drag, keeping the object in the region long enough for the gas to run out," Vieira Neto says. It then becomes a matter of numbers, to a great degree. With thousands of bodies flying around the Solar System, the likelihood of one of them – Ceres – ending up in the asteroid belt becomes high. The simulation shows that it comes to rest in an orbit in that region. But why did it settle there and not move further inwards?

"We observed that planetesimals scattered by the embryos of Uranus and Neptune were implanted in the main belt, losing energy due to gas and mainly entering in resonant orbits with Jupiter," Vieira Neto says. "Using a statistical treatment of the various simulations that were made, we came to the conclusion that the resonances with Jupiter are enough to prevent the gaseous drag taking Ceres out of the main belt region." The computer simulation has also been able to work out where in the outer region Ceres is likely to have formed. It would have needed to have taken place beyond what's called the frost line – the boundary between the warm inner Solar System, due to it being closer to the Sun, and the colder outer Solar System. Bodies beyond that line would be sufficiently cold for volatile compounds such as ammonia, methane, carbon dioxide, carbon monoxide and water to condense into solid ice grains.



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WHERE WAS CERES BORN?

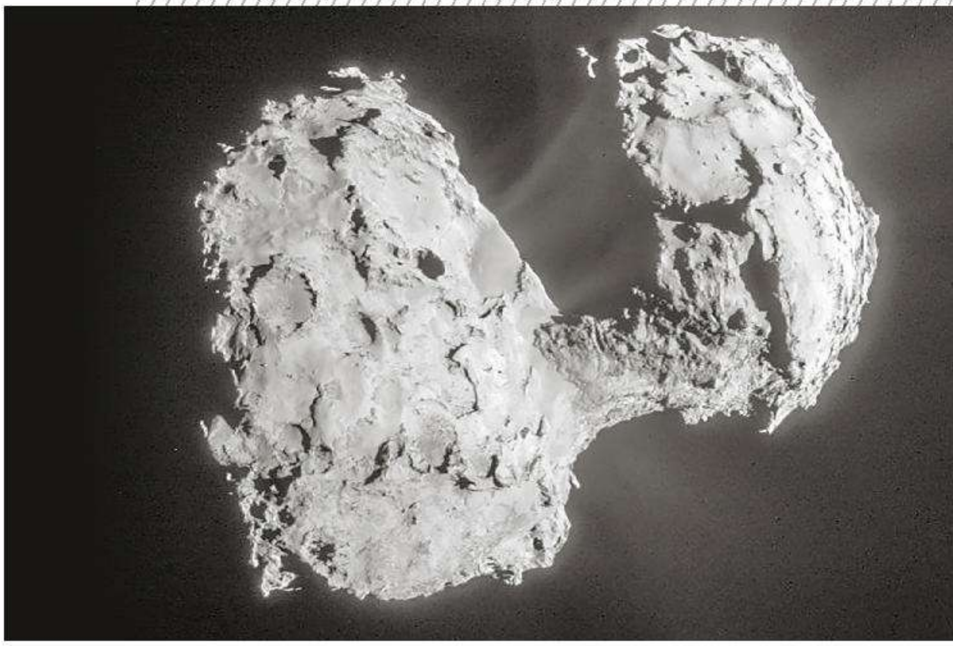
How the dwarf planet is likely to have formed and migrated

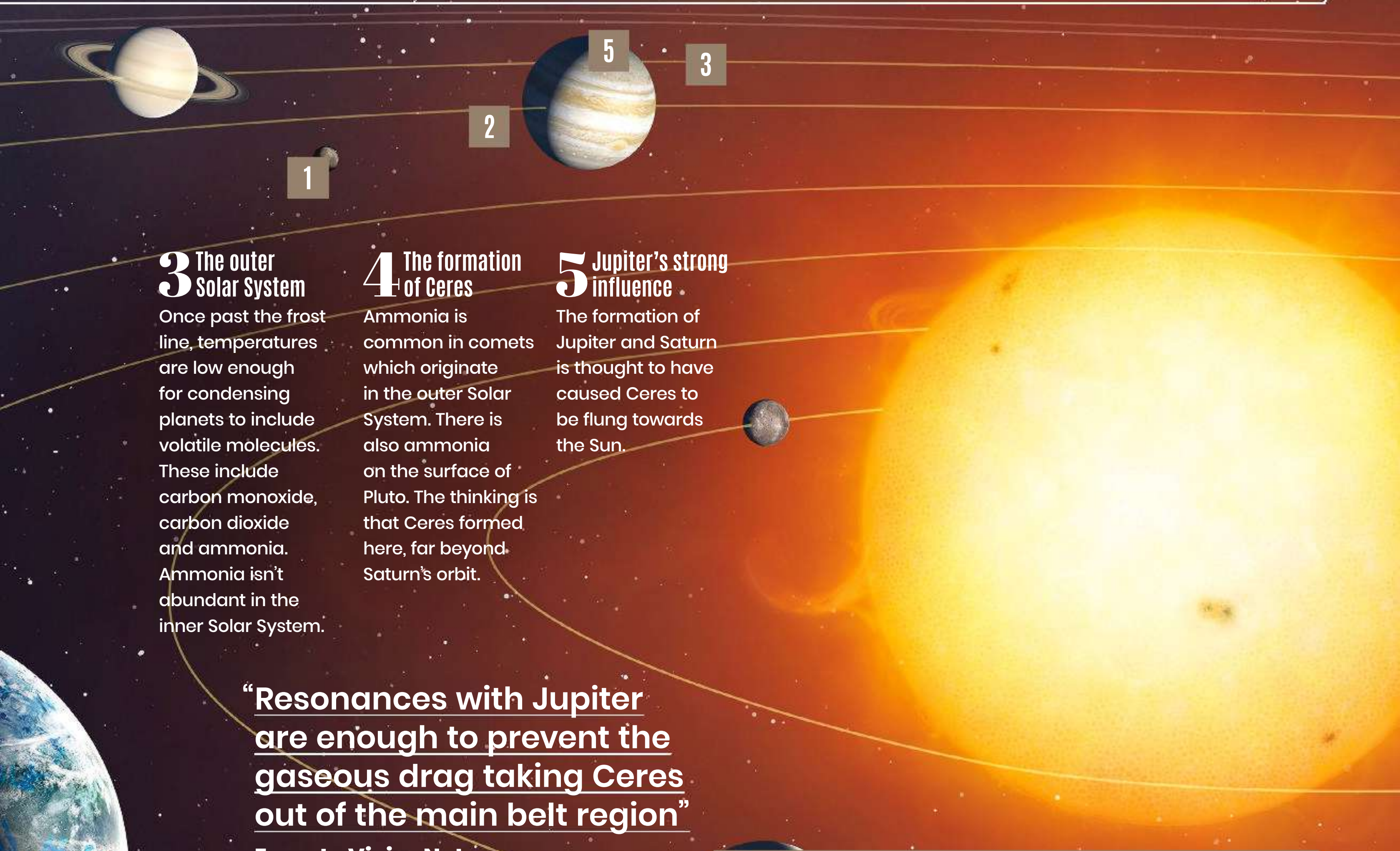
1 Ceres' current location

Ceres is the largest object in the asteroid belt, as well as the only recognised dwarf planet in the inner Solar System.

2 The frost line

The frost line is currently five astronomical units from the Sun. It was about half as close to the Sun when Ceres formed.





3 The outer Solar System

Once past the frost line, temperatures are low enough for condensing planets to include volatile molecules. These include carbon monoxide, carbon dioxide and ammonia. Ammonia isn't abundant in the inner Solar System.

4 The formation of Ceres

Ammonia is common in comets which originate in the outer Solar System. There is also ammonia on the surface of Pluto. The thinking is that Ceres formed here, far beyond Saturn's orbit.

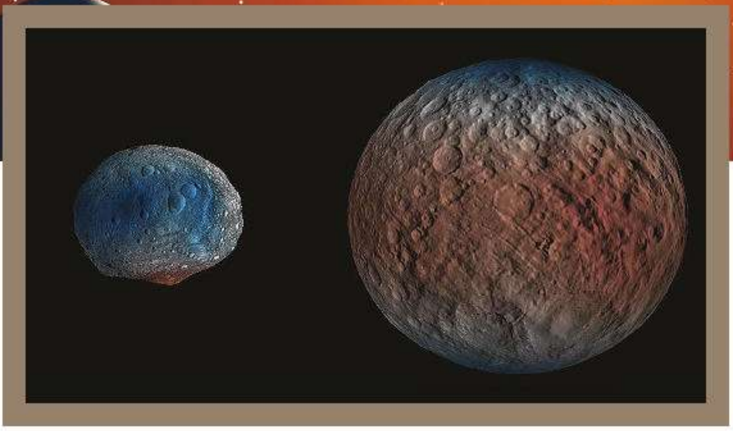
5 Jupiter's strong influence

The formation of Jupiter and Saturn is thought to have caused Ceres to be flung towards the Sun.

> "Resonances with Jupiter are enough to prevent the gaseous drag taking Ceres out of the main belt region"
>
> **Ernesto Vieira Neto**

Today the frost line is near Jupiter's orbit, but it's moved hugely over billions of years. During planetesimal formation, the frost line was 2.7 astronomical units from the Sun – 2.7 times the Sun-Earth distance. That's closer than today because the Sun wasn't as energetic, but the growth of the gas giants had an impact. "The intense gravitational disturbance produced by the growth of these planets may have changed the density, pressure and temperature of the protoplanetary disc, displacing the frost line," Vieira Neto says. "This disturbance in the protoplanetary gas disc may have led the expanding planets to migrate to orbits closer to the Sun as they acquired gas and solids."

But what of those other Ceres-sized mini-planets? According to the modelling, they would have met their fate one way or another. "Of the 3,600 planetesimals, many were scattered to more distant regions of the Solar System," Vieira Neto tells **All About Space**. "Some must have scattered to the region of the rocky planets, helping to form Venus, Mars and Earth. Many others fell into the Sun." And that, as we can see, leaves Ceres, a dwarf planet just begging for further study. With Dawn now history, surely a follow-up trip is in order. As it is, it provides a tantalising clue as to how the Solar System formed. It appears it was lucky in being able to survive such a violent beginning – and astronomers are lucky that it did.

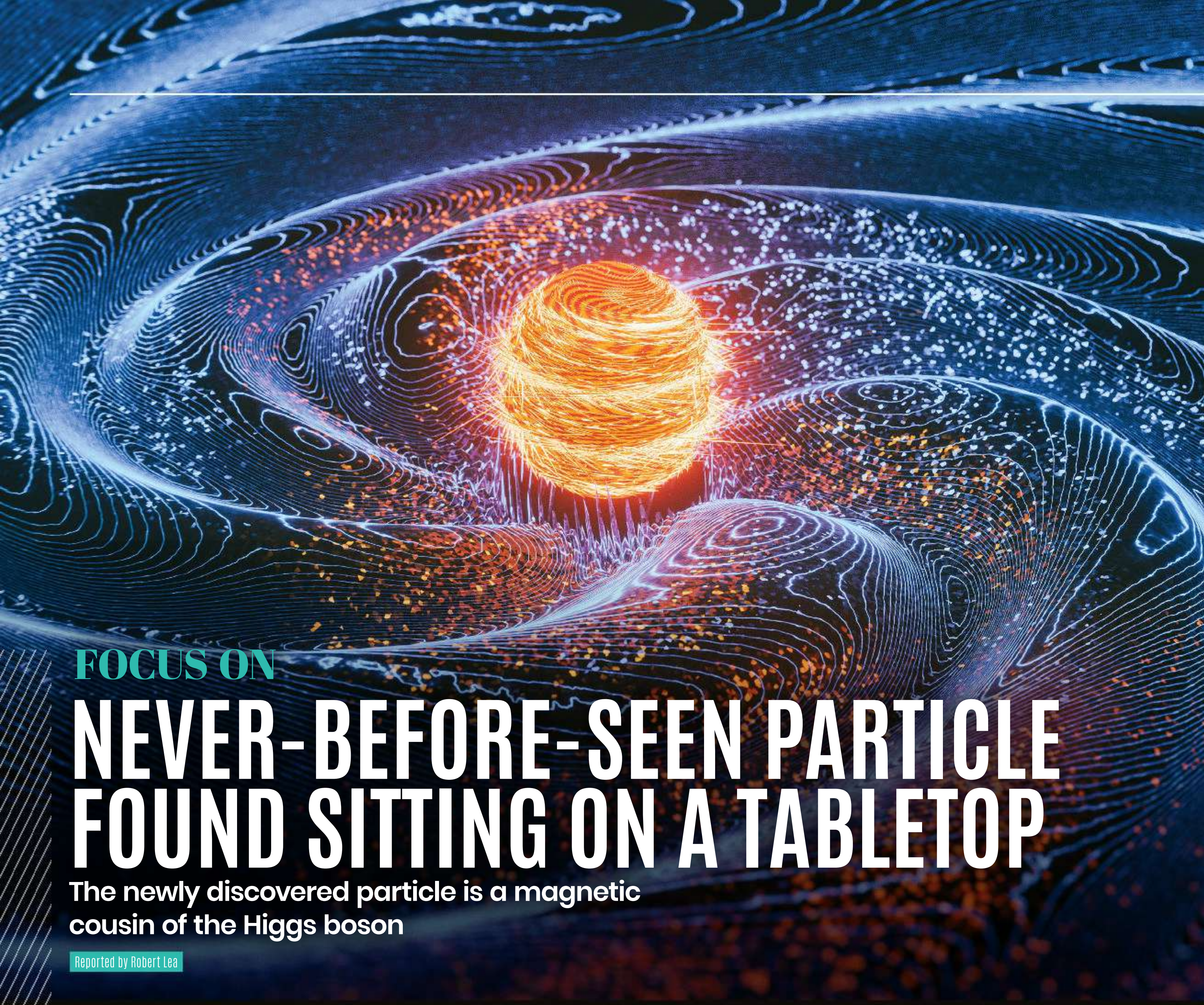


▲ Images captured by the Dawn spacecraft show an abundance of water ice on Ceres

◀ Comets like Rosetta originated in the outer Solar System, where ammonia and ice are able to survive. In the inner Solar System they drift as vapour, hence why comets appear to have a tail when we observe them

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.

© NASA; Getty



FOCUS ON

NEVER-BEFORE-SEEN PARTICLE FOUND SITTING ON A TABLETOP

The newly discovered particle is a magnetic cousin of the Higgs boson

Reported by Robert Lea

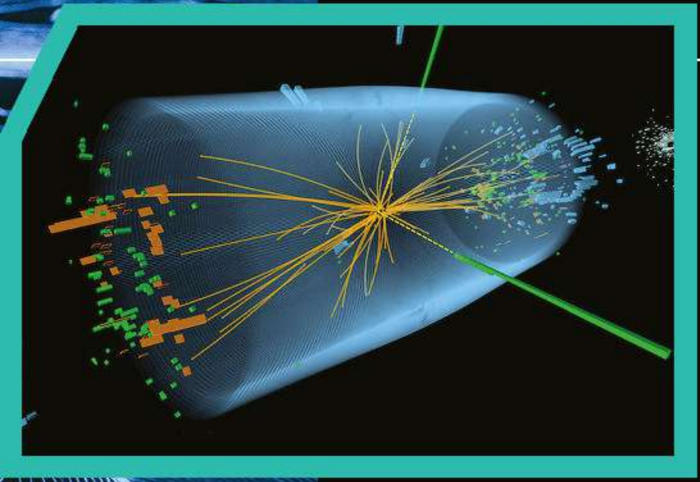
Researchers have discovered a new particle that's a magnetic relative of the Higgs boson. Whereas the discovery of the Higgs boson required the tremendous power of the Large Hadron Collider (LHC), this particle, dubbed the axial Higgs boson, was found using an experiment that would fit on a small kitchen countertop. As well as being a first in its own right, this magnetic cousin of the Higgs boson – the particle responsible for granting other particles their mass – could be a candidate for dark matter, which accounts for 85 per cent of the total mass of the universe but only reveals itself through gravity.

"When my student showed me the data I thought she must be wrong," Kenneth Burch, a professor of physics at Boston College and lead researcher of the team that made the discovery, said. "It's not every day you find a new particle sitting on your tabletop." The axial Higgs boson differs from the Higgs boson, which was first found by detectors at the LHC a decade ago in 2012, because it has a magnetic moment – a magnetic strength or orientation that creates a magnetic field. As such, it requires a more complex theory to describe it than its non-magnetic mass-granting cousin.

In the Standard Model, particles emerge from different fields that permeate the universe, and some of these particles shape the universe's fundamental forces – photons mediate electromagnetism and hefty particles known as W and Z bosons mediate the weak nuclear force, which governs nuclear decay at subatomic levels. When the universe was young and hot, however, electromagnetism and the weak force were one thing, and all of these particles were nearly identical. As the universe cooled, the electroweak force split, causing the W and Z bosons to gain mass and behave very

> "It's not every day you find a new particle sitting on your tabletop"
> **Kenneth Burch**

Ⓐ The axial Higgs boson was found unexpectedly



The Compact Muon Solenoid (CMS) experiment at the LHC found the Higgs boson in 2012

differently from photons, a process physicists have called 'symmetry breaking.' But how exactly did these weak-force-mediating particles get so heavy?

It turns out these particles interacted with a separate field: the Higgs field. Perturbations in that field gave rise to the Higgs boson and lent the W and Z bosons their heft. The Higgs boson is produced in nature whenever such symmetry is broken. "However, typically only one symmetry is broken at a time, and thus the Higgs is just described by its energy," Burch said. The theory behind the axial Higgs boson is more complicated. "In the case of the axial Higgs boson it appears multiple symmetries are broken together, leading to a new form of the theory and a Higgs mode that requires multiple parameters to describe it – specifically energy and magnetic momentum," Burch said.

Burch explained that the original Higgs boson doesn't couple directly with light, meaning it has to be created by smashing other particles together with enormous magnets and high-powered lasers while also cooling samples to extremely cold temperatures. It's the decay of those original particles into others that pop fleetingly into existence that reveals the presence of the Higgs. The axial Higgs boson, on the other hand, arose when room-temperature quantum materials mimicked a specific set of oscillations called the axial Higgs mode. Researchers then used the scattering of light to observe the particle.

"We found the axial Higgs boson using a tabletop optics experiment by focusing on a material with a unique combination of properties," Burch continued. "We used rare-earth tritelluride (RTe3) [a quantum material with a highly two-dimensional crystal structure]. The electrons in RTe3 self-organise into a wave where the density of the charge is periodically enhanced or reduced." The size of these charge density waves, which emerge above room temperature, can be modulated over time, producing the axial Higgs mode.

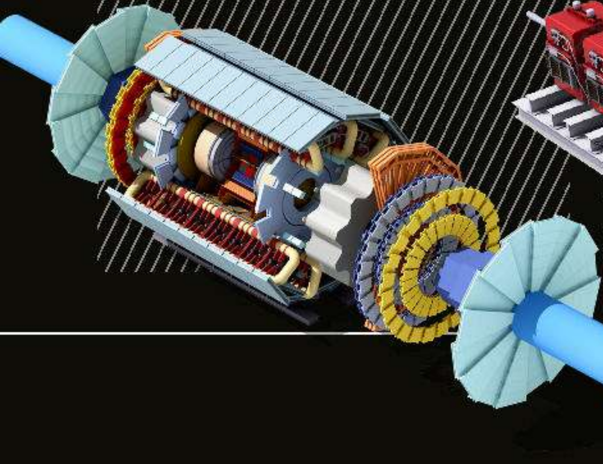
In the new study, the team created the axial Higgs mode by sending laser light of one colour into the RTe3 crystal. The light scattered and changed to a colour of lower frequency in a process known as Raman scattering, and the energy lost during the colour change created the axial Higgs mode. The team then rotated the crystal and found that the axial Higgs mode also controls the angular momentum of the electrons, or the rate at which they move in a circle, in the material, meaning this mode must also be magnetic. "Originally we were simply investigating the light-scattering properties of this material. When carefully examining the symmetry of the response – how it differed as we rotated the sample – we discovered anomalous changes that were the initial hints of something new," Burch explained. "As such, it's the first such magnetic Higgs to be discovered and indicates the collective behaviour of the electrons in RTe3 is unlike any state previously seen in nature."

LARGE HADRON COLLIDER

Experiments at the famous particle accelerator

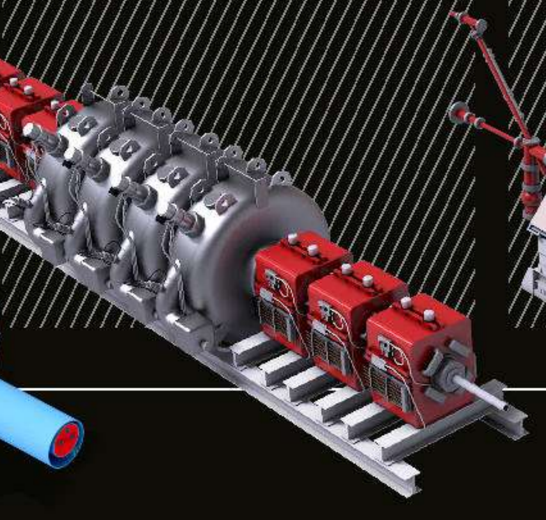
ALPHA

The Antihydrogen Laser PHysics Apparatus makes, captures and studies atoms of antihydrogen and compares them with hydrogen.



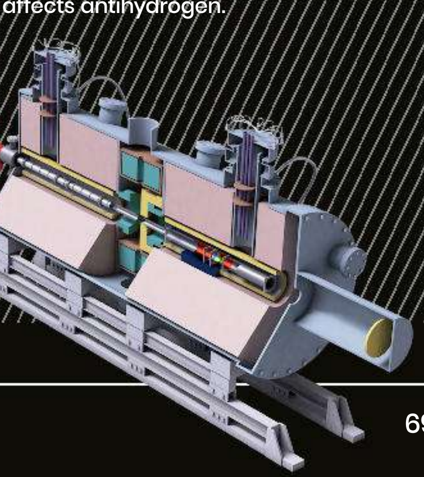
AD

The Antiproton Decelerator is a source of antiprotons for use in other antimatter experiments at the LHC.



AEgIS

The Antihydrogen Experiment: gravity, Interferometry, Spectroscopy looks at how Earth's gravity affects antihydrogen.



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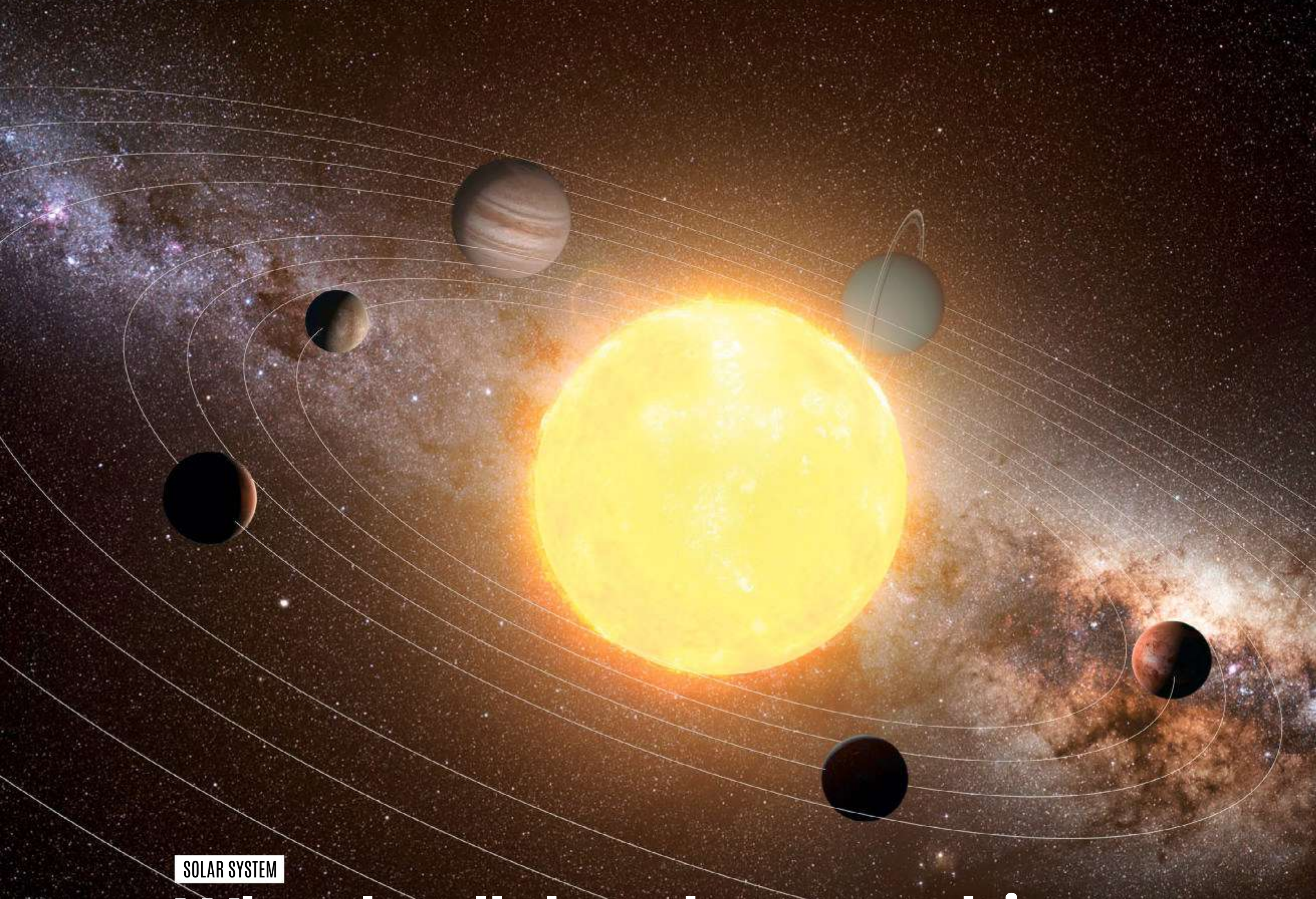


SOLAR SYSTEM

Why do all the planets orbit the Sun in the same direction?

The reason is what's known as 'conservation of angular momentum'. Think of a figure skater doing a spin and pulling in their arms. The Solar System formed from the collapse of a huge cloud of gas and dust. As it collapsed, any net rotation would cause most of the cloud to settle into a flattened, rotating disc. Collisions between dust and friction within the gas would drag material into the same motions as the majority of the gas and dust. Collisions between dust grains would build up to larger bodies – planetesimals – which would ultimately collide to form the planets. The general revolution of the disc would transfer to the rotating planets and to the Sun itself.

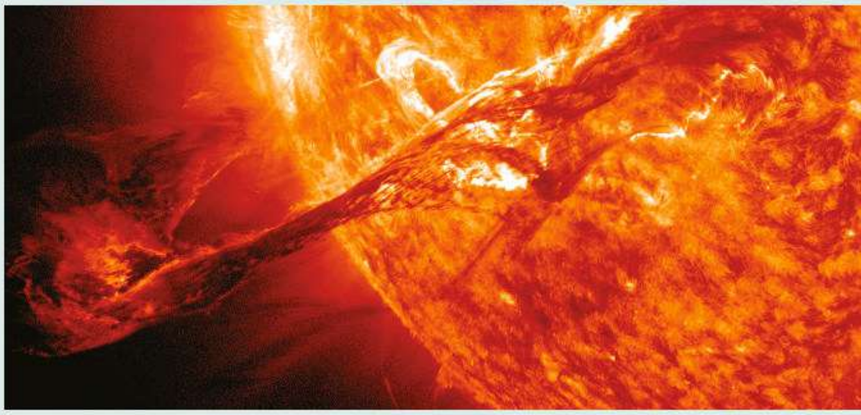
Most of the angular momentum of the Solar System is in the outer planets, both in rotation and orbital motion. The Sun itself rotates very slowly, about once a month, while Jupiter and Saturn rotate once every ten hours. Among the planets, only Venus and Uranus fail to share this common rotation. Venus rotates backwards – or it's tipped upside down – while Uranus is tipped so its axis is close to the plane of its orbit. We believe these are due to violent collisions when the Solar System was still very young.

Dr George Spagna, chair of the physics department at Randolph-Macon College

All eight planets of the Solar System follow an anti-clockwise path around the Sun

STARS

If the Sun erupted with a superflare, how harmful would it be for life on Earth?

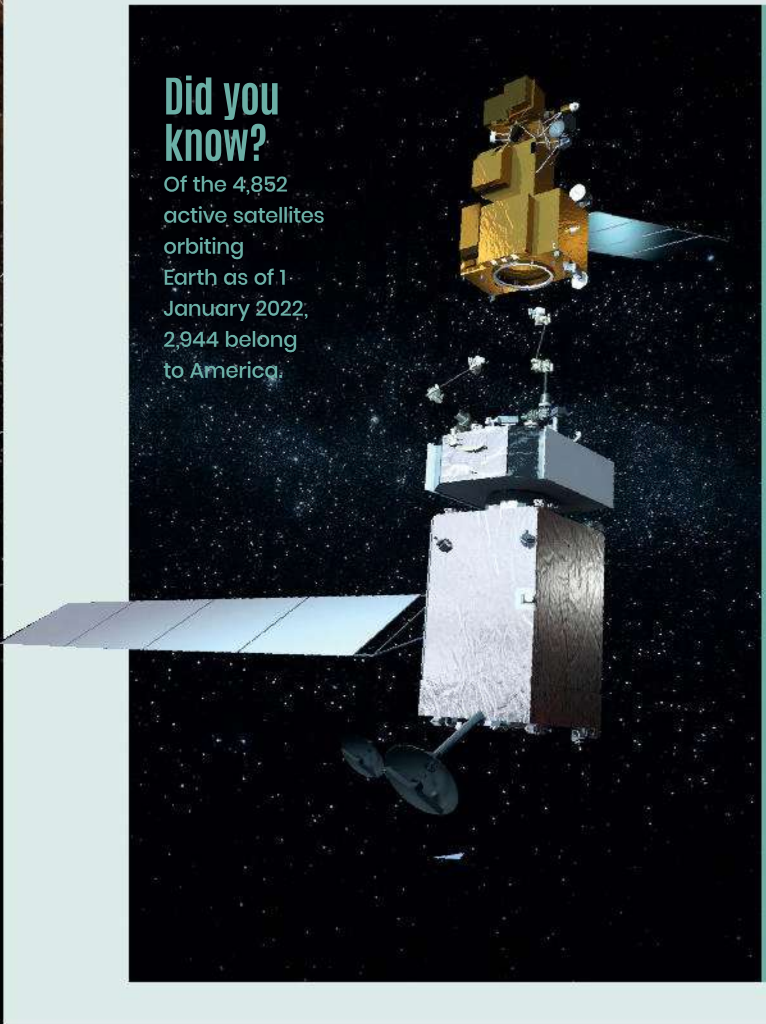


▲ There is a colossal size difference between Earth and one of the Sun's superflares

Superflares emit large amounts of dangerous high-energy particles, but life on Earth is protected by a thick atmosphere and there are almost no effects. However, now is the Space Age – there are astronauts in space, and maybe also on the Moon or Mars in the near future. Superflares can cause risks for them since they don't have the shield of the thick atmosphere, so special preparations should be made.

Although superflares do not affect survival for life directly – no life extinction is expected to occur because of superflares – our daily life can be severely damaged by superflares. Now our societies and our daily lives are strongly supported by technologies using electricity and satellite communication, for example GPS. Large plasma ejections called coronal mass ejections, or CMEs, caused by superflares can generate a large magnetic storm in Earth's magnetosphere, and this can cause severe damage to electric equipment, for example transformers, and satellites. One example is the large blackout in Quebec, Canada, in 1989 caused by a relatively large solar flare. At this point, life on Earth – especially human life – could potentially experience a severe solar eruption.

Dr Yuta Notsu, research associate at the University of Colorado Boulder



▼ Artist's concept of OSAM-1

Did you know?

Of the 4,852 active satellites orbiting Earth as of 1 January 2022, 2,944 belong to America.

SPACE EXPLORATION

How do you service a satellite?

Though the vast majority of satellites were not designed to be serviced, NASA is looking into ways to make it possible. Similar to how a car can be repaired and receive more fuel, satellite servicing seeks to make the same options available to satellites. Most satellites use fuel to maintain orbit control, so the depletion of fuel can end its life. Parts wear out and components fail or become obsolete, which can also end or limit a satellite's usefulness.

In order to service a satellite, a servicer must meet up with the satellite while flying thousands of miles per hour. A servicer needs to manoeuvre and perform autonomous rendezvous and proximity operations using cameras, machine-vision systems and high-speed avionics. Once the servicer mates with the satellite, dexterous robots and specialised tools can be used to transfer fuel to the satellite. The first-ever refuelling of a satellite not designed to be serviced will be demonstrated by NASA's On-orbit Servicing, Assembly and Manufacturing 1 (OSAM-1) mission in the next few years.

Brent Robertson, NASA project manager for the On-orbit Servicing, Assembly and Manufacturing 1 (OSAM-1) mission

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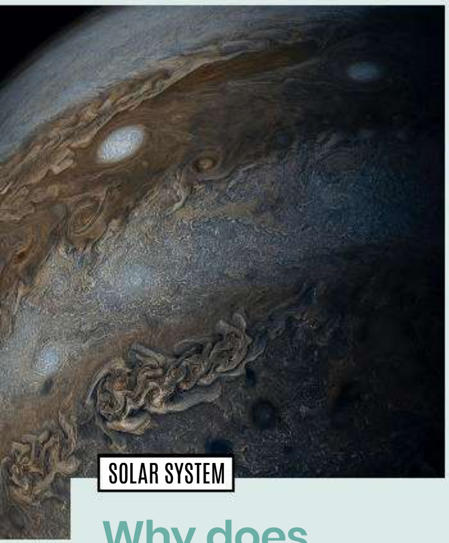


B The zones and bands of Jupiter have been a mystery to astronomers ever since the telescope was first invented

SOLAR SYSTEM

Why does Jupiter have cloud bands?

The light stripes are called zones, while the dark ones are belts. These bands are driven by powerful atmospheric flows that travel in opposite directions at speeds reaching some 540 kilometres (340 miles) per hour.

We know from observations that the temperature and composition of the zones differ from the belts. Zones are colder, which corresponds to gas upwellings, and are rich in frozen ammonia, hence their colour. Belts are hotter, which means that the gas flow is downwelling.

Two main ideas compete to describe their origin. First that they are generated by deep internal convection, a process where the motion of the gas transfers heat. Since Jupiter's atmosphere and interior are connected, the zonal flows would extend substantially into the conducting hydrogen core. Second is that they're surface phenomena, primarily maintained by the temperature difference between the zones and belts. Recent data suggests the former, which if confirmed would be an amazing revelation.

Dr Mohamed Zaghoo, research associate at the University of Rochester, New York

SPACE EXPLORATION

How important is astrobotany research for future space exploration efforts?

Astrobotany is going to be critical for future space exploration, particularly in the realm of providing caloric support for extended spaceflight missions. In the near future, it's unlikely we will use plants as an oxygen source in a bioregenerative life-support system (BLSS) because gas exchange is more easily controlled manually than relying on plants to produce enough oxygen to support a crew. The science is not precise or reliable enough to depend on just plants for oxygen. However, it will be of huge benefit to supplement caloric intake with plants in space.

The sustainability of harvesting in space is another perk that cannot go overlooked. Resupplies to the International Space Station (ISS) are necessary, but resupplies beyond the relatively short distance to the ISS could become impossible or not time or cost effective. Future missions will need to rely on sustainable plant growth to supplement caloric intake, and the added benefit is that it is supposed to be an immense help for astronauts' mental health.

Kai Rasmussen, director of astrobotany.com

A Growing food in space is essential for long-duration spaceflight and future colonisation

ASTROPHYSICS

How is dark matter located if we can't see it?

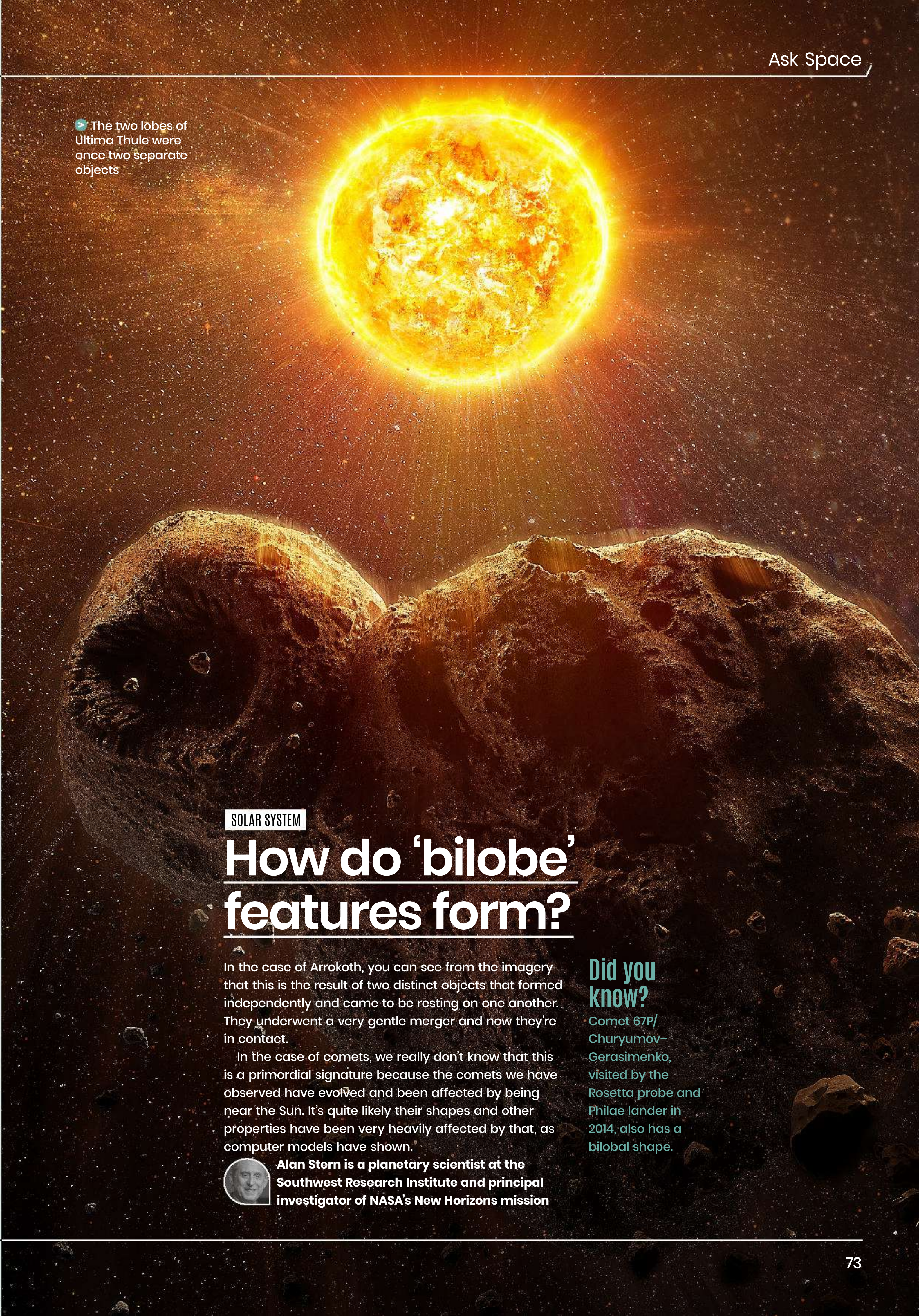
Dark matter is invisible, but gives itself away by moving other things. Look out of your window: are the trees moving? You can't see the wind, but it must be blowing because leaves are twitching. Stars and galaxies are leaves in the cosmic wind. The distance between galaxies was gradually controlled after the Big Bang by the gravitational tug from dark matter. The largest clumps of dark matter still fling galaxies around today – faster than galaxies could move if pulled only by each other's gravity.

A clump of dark matter in our Milky Way whips individual stars into fast orbits. Smaller clumps of dark matter have pulled stars away from streams that used to be orbiting together. The cosmic soup is lumpy. But the lumpiness depends on its ingredients. If dark matter feels forces other than gravity or is made of certain particles, lumps just smaller than those known would have dissolved. To learn what dark matter is, we are watching ever more sensitive leaves – faint stars and even rays of light – for the indirect flutter of the tiniest passing breeze.

Richard Massey, Institute for Computational Cosmology at Durham University

C Though dark matter is invisible, its influence can be seen

© © NASA/JPL-Caltech; NASA/ESA; Getty;



The two lobes of Ultima Thule were once two separate objects

SOLAR SYSTEM

How do ‘bilobe’ features form?

In the case of Arrokoth, you can see from the imagery that this is the result of two distinct objects that formed independently and came to be resting on one another. They underwent a very gentle merger and now they’re in contact.

In the case of comets, we really don’t know that this is a primordial signature because the comets we have observed have evolved and been affected by being near the Sun. It’s quite likely their shapes and other properties have been very heavily affected by that, as computer models have shown.

Alan Stern is a planetary scientist at the Southwest Research Institute and principal investigator of NASA’s New Horizons mission

Did you know?

Comet 67P/Churyumov–Gerasimenko, visited by the Rosetta probe and Philae lander in 2014, also has a bilobal shape.

SUMMER DEEP-SKY DELIGHTS

The lighter, warmer months are the perfect time for tracking down some of the most fascinating objects

Written by Stuart Atkinson

SOUTH
SW
WEST

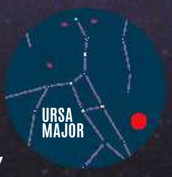
Many astronomers and sky-watchers go into a reverse hibernation during the summer months because they think there's nothing to see… they're wrong. Although the summer sky never gets anywhere near as dark as the winter sky, it gets just dark enough for many beautiful objects to be seen – clouds of gas called nebulae, sparkling star clusters and beautiful spiral galaxies. .

Nebulae are fascinating places where new stars are being born or where old stars are illuminating gas around them. Star clusters are groups of stars all flying through space together. Spiral galaxies are vast collections of billions of stars in winding arms. Although you might see the brightest of these so-called 'deep-sky objects' through your telescope from your garden, they'll look so much more beautiful if you go into the countryside to somewhere properly dark, unspoiled by light pollution. There you'll see the Milky Way in all its glory, airbrushed across the sky, and will be able to find lots of deep-sky objects too.

Choose a good place to stargaze

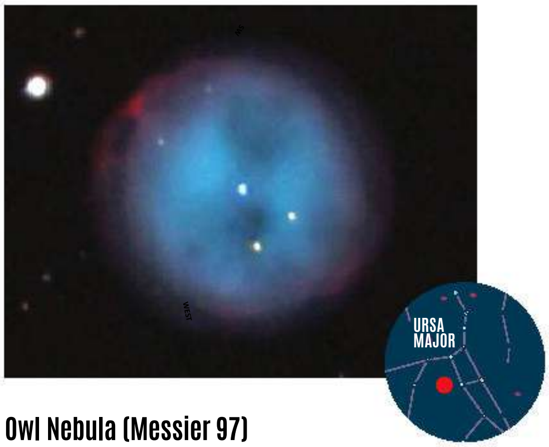
Somewhere with no lights, no passing traffic and no large obstructions on the horizon – trees, buildings or hills – is the best place to stargaze from.

Bode's Galaxy (Messier 81)



Visible all night during summer

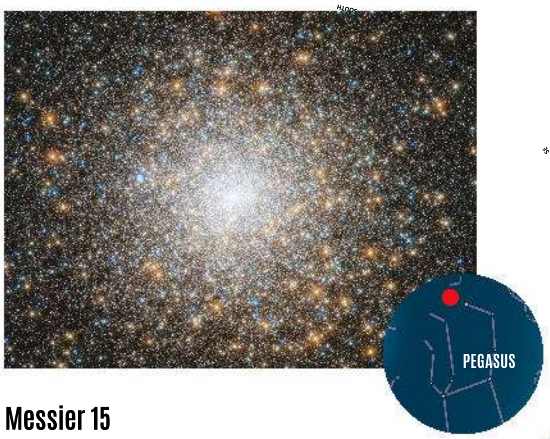
With a pair of binoculars, Bode's Galaxy looks like a small, oval-shaped patch of light. In a telescope it is much bigger and brighter, with two very obvious spiral arms winding away from its compact centre. Big telescopes reveal clumpiness in the arms.



Owl Nebula (Messier 97)

Visible all night during summer

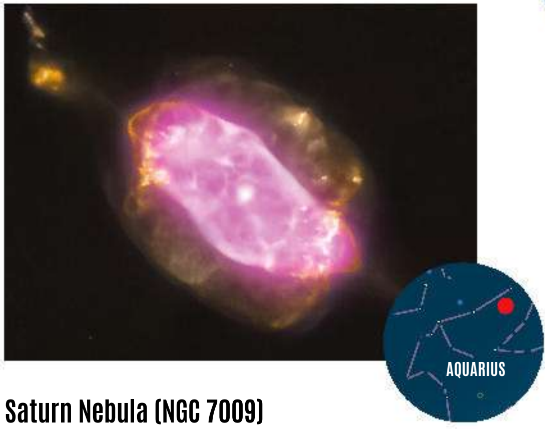
Through small telescopes it looks like an out-of-focus star; even in a six-inch telescope under a dark sky it's a round smudge. A ten-inch or larger scope will show it as a round, misty cloud with two darker regions inside.



Messier 15

Visible throughout the night during summer

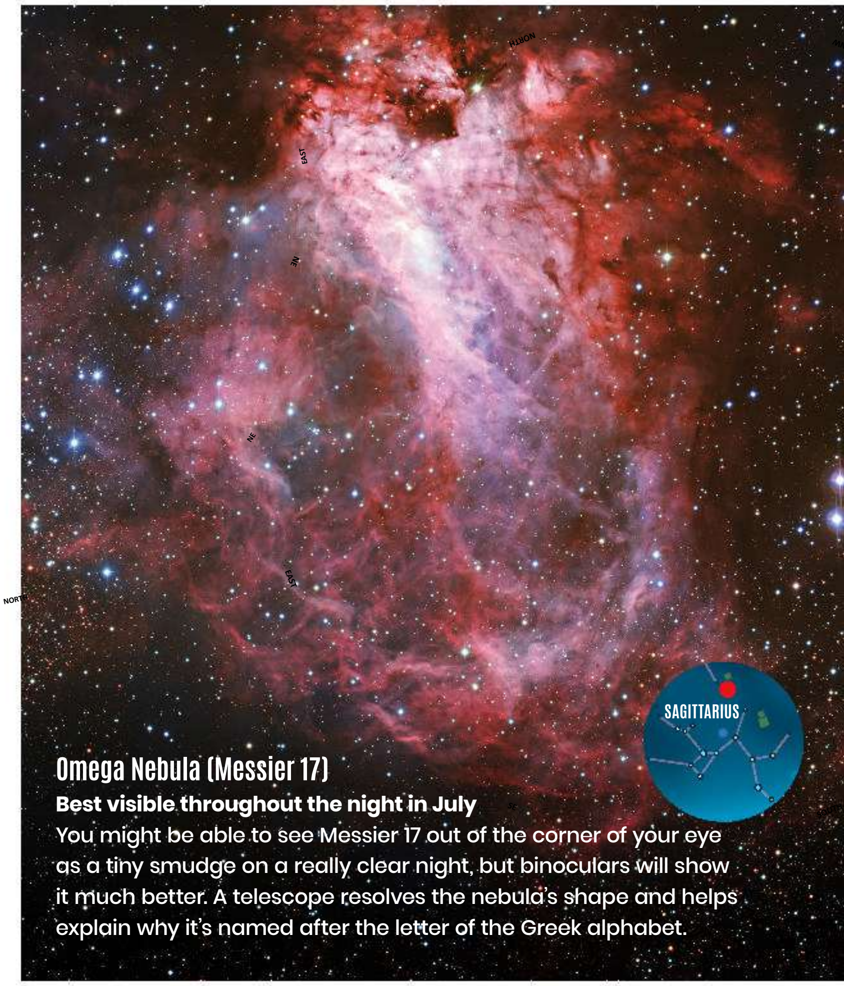
Between 12 and 13.2 billion years old, Messier 15 is just a little younger than the universe. In binoculars it's merely an out-of-focus star. The larger the telescope, the more stars you will see in this lovely cluster.



Saturn Nebula (NGC 7009)

Visible throughout the night during summer

Looking at this planetary nebula through a small telescope, it looks like a tiny, slightly green-hued out-of-focus star. But through larger telescopes the nebula begins to resemble Saturn, with faint 'arms' around it.



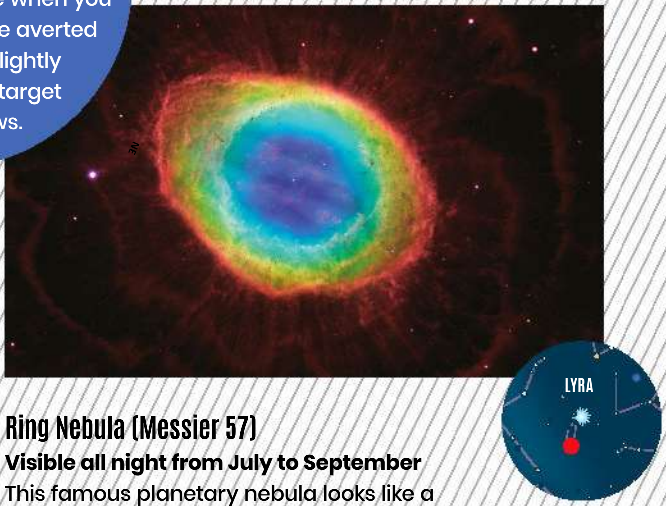
Omega Nebula (Messier 17)

Best visible throughout the night in July

You might be able to see Messier 17 out of the corner of your eye as a tiny smudge on a really clear night, but binoculars will show it much better. A telescope resolves the nebula's shape and helps explain why it's named after the letter of the Greek alphabet.

Make the most of your peripheral vision

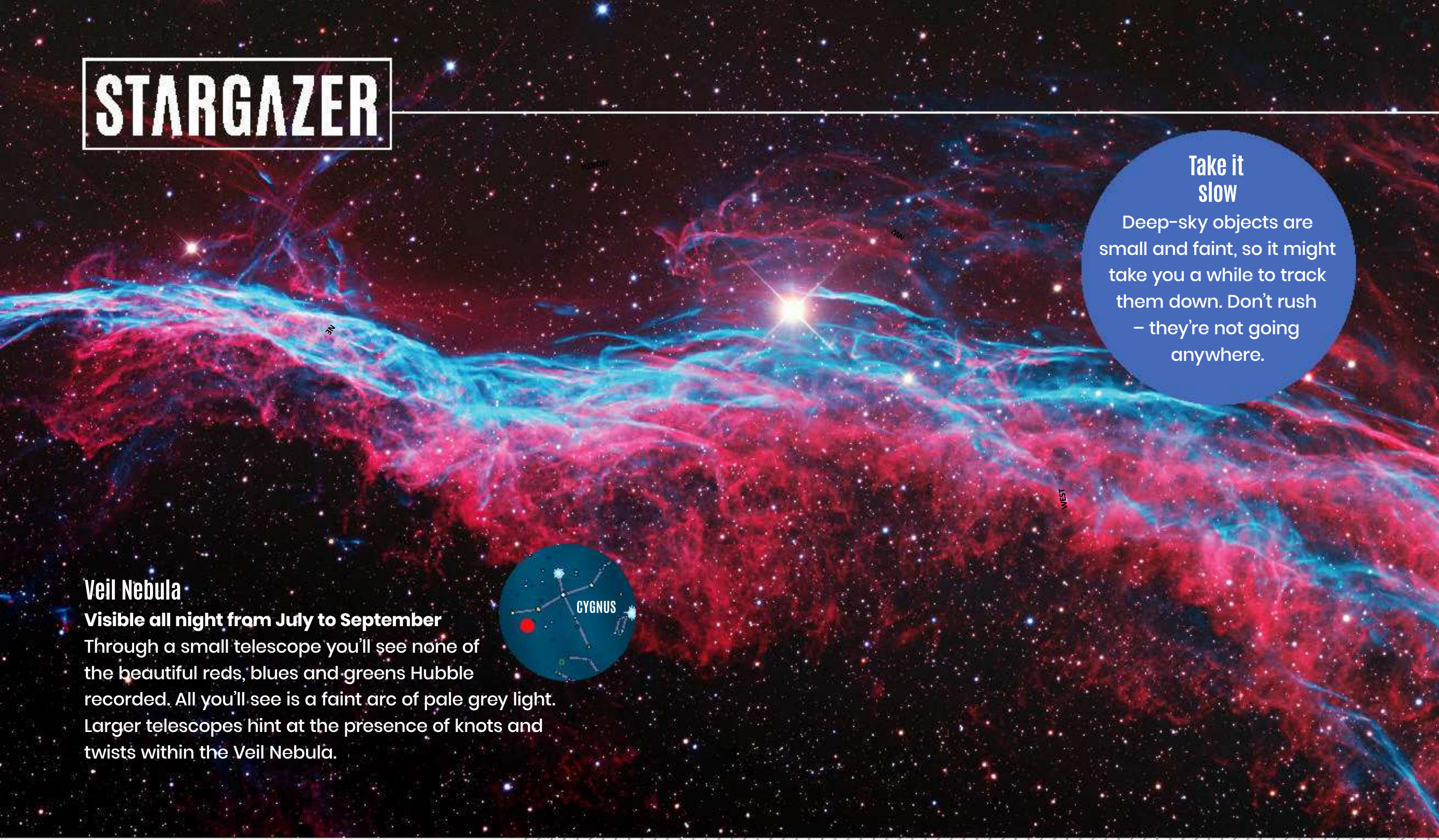
Having found your nebula, galaxy or cluster, you may find that it's difficult to see when you look directly at it. Use averted vision and look slightly away from your target for good views.



Ring Nebula (Messier 57)

Visible all night from July to September

This famous planetary nebula looks like a tiny, pale smoke ring in small instruments. Bigger telescopes reveal clumps in the ring and the star at its centre. Through binoculars you'll see a tiny blurry disc.



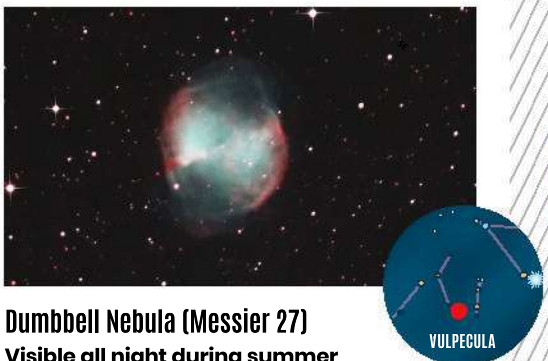
Veil Nebula

Visible all night from July to September

Through a small telescope you'll see none of the beautiful reds, blues and greens Hubble recorded. All you'll see is a faint arc of pale grey light. Larger telescopes hint at the presence of knots and twists within the Veil Nebula.

Take it slow

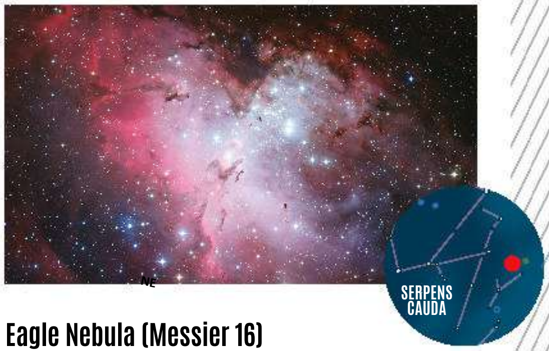
Deep-sky objects are small and faint, so it might take you a while to track them down. Don't rush – they're not going anywhere.



Dumbbell Nebula (Messier 27)

Visible all night during summer

If you have a really dark sky, binoculars will show Messier 27 as a tiny blurry spot. A small telescope's view isn't much better. It takes a larger telescope to see Messier 27's twin fan-shaped lobes of gas.



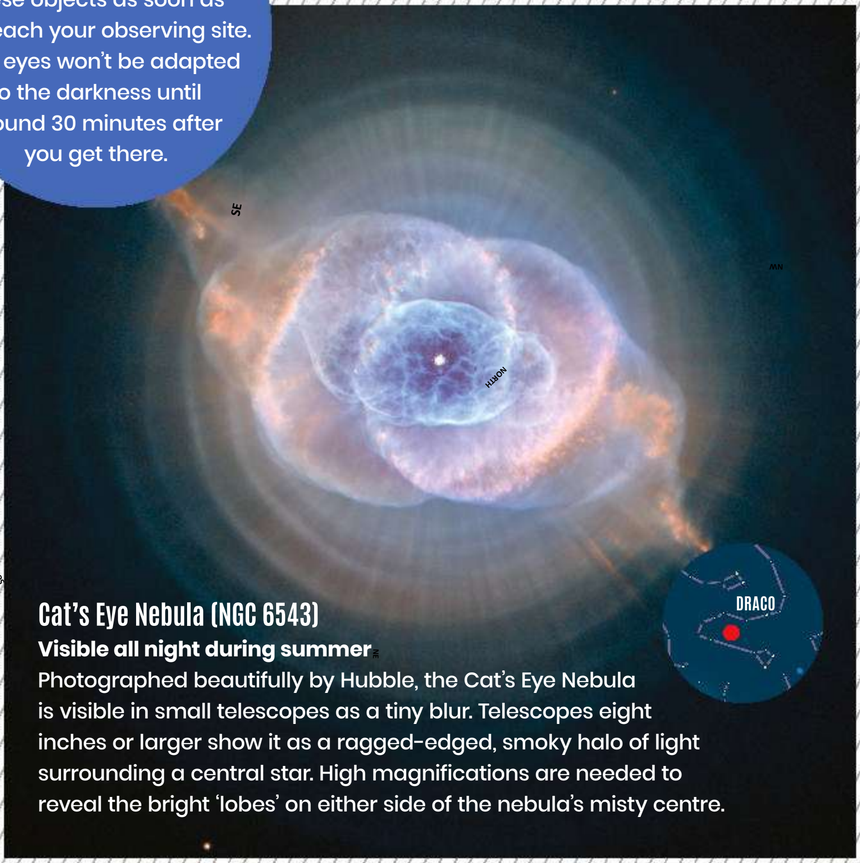
Eagle Nebula (Messier 16)

Visible all night in June and July

Hubble took a spectacular photo of the nebulae, including its famous 'Pillars Of Creation'. Unfortunately you can only see the nebula as a tiny smudge through binoculars and smaller telescopes.

Let your eyes adapt to the dark

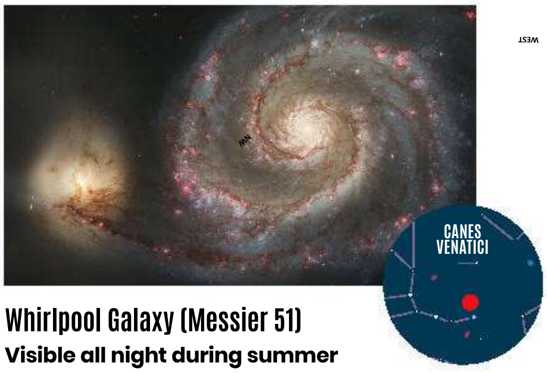
Don't start hunting for these objects as soon as you reach your observing site. Your eyes won't be adapted to the darkness until around 30 minutes after you get there.



Cat's Eye Nebula (NGC 6543)

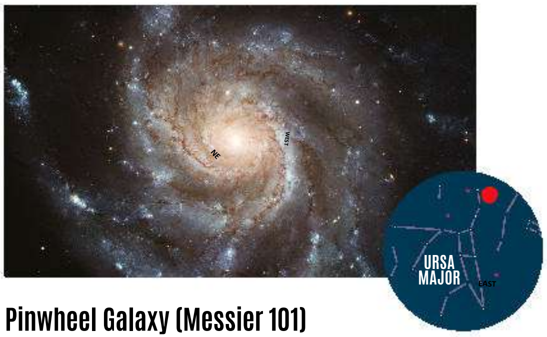
Visible all night during summer

Photographed beautifully by Hubble, the Cat's Eye Nebula is visible in small telescopes as a tiny blur. Telescopes eight inches or larger show it as a ragged-edged, smoky halo of light surrounding a central star. High magnifications are needed to reveal the bright 'lobes' on either side of the nebula's misty centre.



Whirlpool Galaxy (Messier 51)

Visible all night during summer
One of the most famous spirals, through binoculars it's just a fuzzy star. A small telescope shows it as an elongated, fuzzy smudge. It takes a big telescope to reveal its stunning spiral arms.

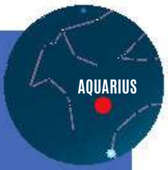


Pinwheel Galaxy (Messier 101)

Visible all night during summer
It's unfortunate we see this lovely galaxy face-on as that spreads its light out over a wide area, reducing its brightness. But it's still bright enough to see through binoculars.

Helix Nebula (NGC 7293)

Best visible all night from July to September
Binoculars show it as a tiny, pale smudge. In a small telescope the nebula looks much more like a smoke ring. Larger telescopes show the knots and clumps that Hubble has photographed so beautifully.



Avoid the Moon

Moonlight drowns out the faint light of deep-sky objects. On a night when there's no Moon in the sky you will have more success.

SAGITTARIUS

Lagoon Nebula (Messier 8)

Visible through the night in June and July
Messier 8 would be an easy naked-eye object if it were high in the dark winter sky, but low in the bright summer sky it's more challenging. However, under a dark sky it can be glimpsed as a definite smudge. Through binoculars and small telescopes it looks like a pair of grey smudges.

WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

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15 JULY

Conjunction between the Moon and Saturn in Capricornus

15 JULY

The Moon and Saturn make a close approach, within 3°48' of each other in Capricornus

19 JULY

Conjunction between the Moon and Jupiter in Cetus

19 JULY

The Moon and Jupiter make a close approach, within 1°58' of each other in Cetus

19 JULY

Conjunction between the Moon and Mars in Aries

20 JULY

Pluto reaches opposition in Sagittarius, with a faint magnitude of +14.9

21 JULY

The Moon and Mars make a close approach, within 58.3' of each other in Aries

21 JULY

The Moon passes in front of Mars, creating a lunar occultation visible from parts of Eastern Asia and the US

29 JULY

The Piscis Austrinid meteor shower reaches its peak

30 JULY

The Southern Delta Aquariid meteor shower reaches its peak

1 AUGUST

Conjunction between Mars and Uranus in Aries

1 AUGUST

Comet C/2017 K2 (PanSTARRS) reaches a predicted magnitude of +8.6 in Scorpius

10 AUGUST

Mercury reaches its highest point in the evening sky, shining at magnitude +0.2

Naked eye

TAKE CARE!
Naked eye warning

Binoculars

Small telescope

Medium telescope

Large telescope

Solar eclipse

Solstice

22 JULY

The Moon passes in front of Uranus, creating a lunar occultation visible from parts of Brazil

22 JULY

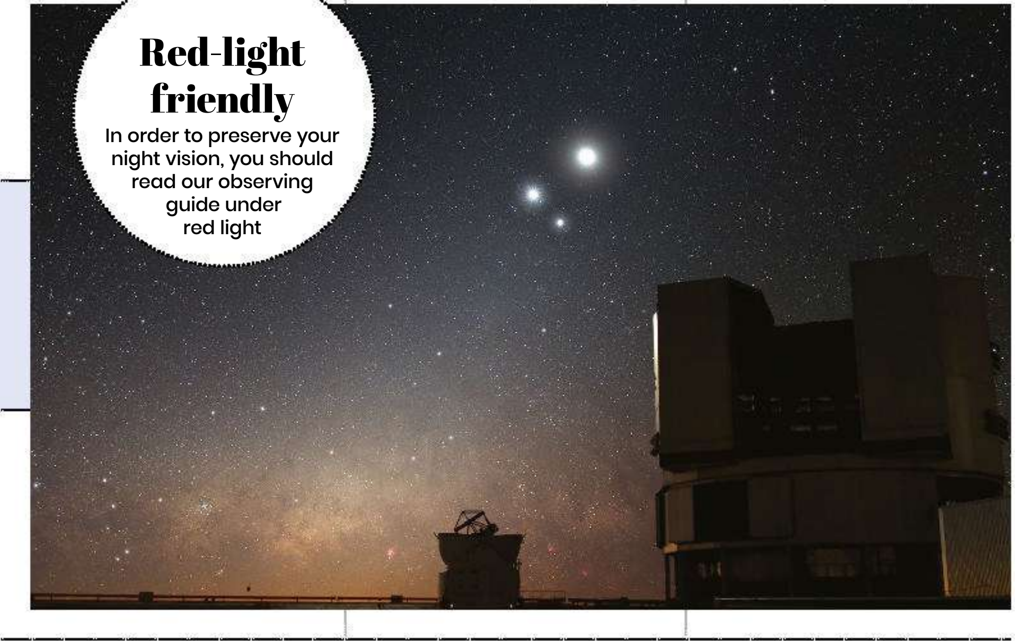
The Moon and Uranus make a close approach, within 13.3' of each other in Aries

28 JULY

Jupiter enters retrograde motion, halting its eastward movement and moving westwards instead

Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light



Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds since as Earth rotates on its axis, we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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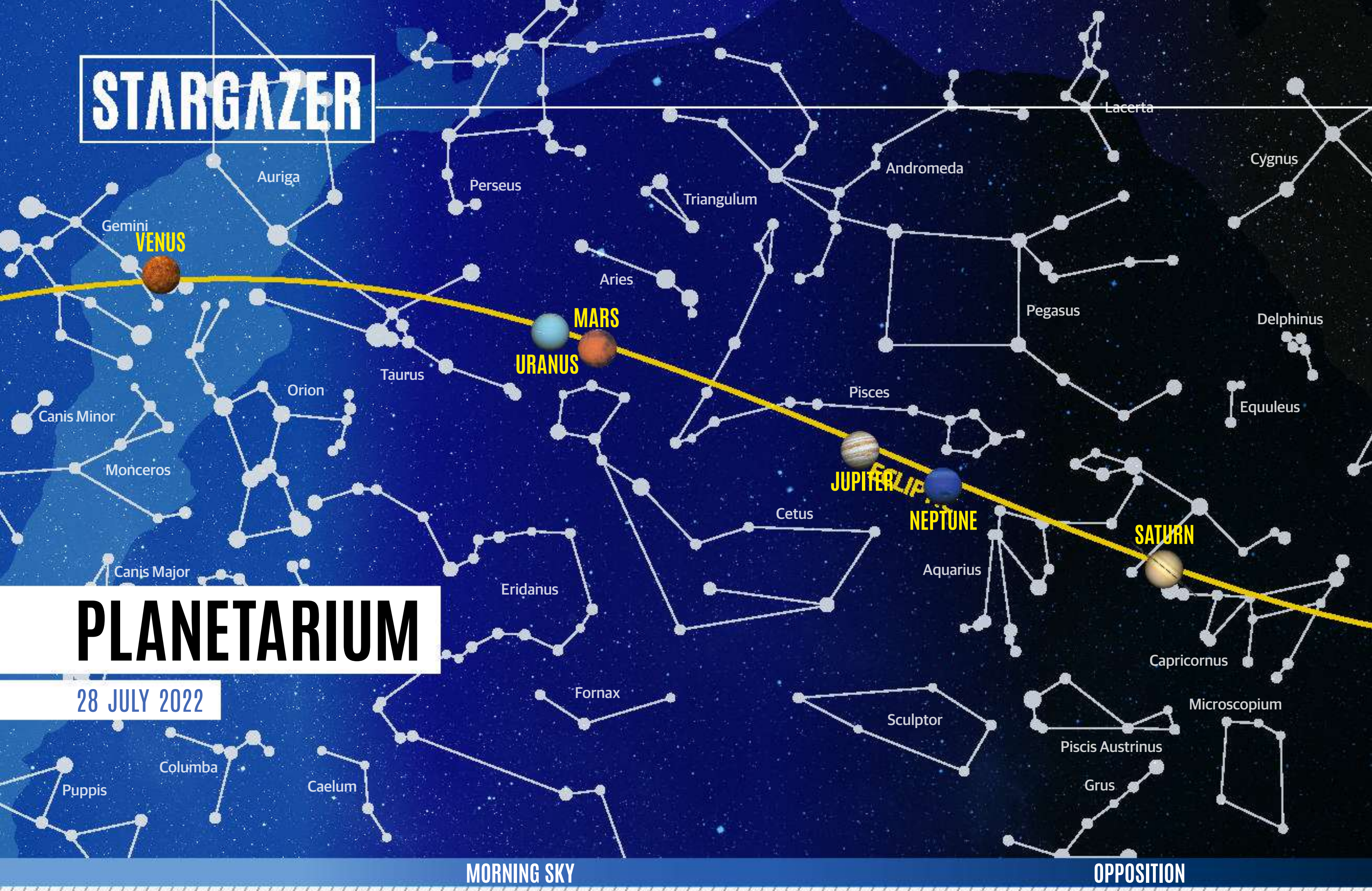
STARGAZER

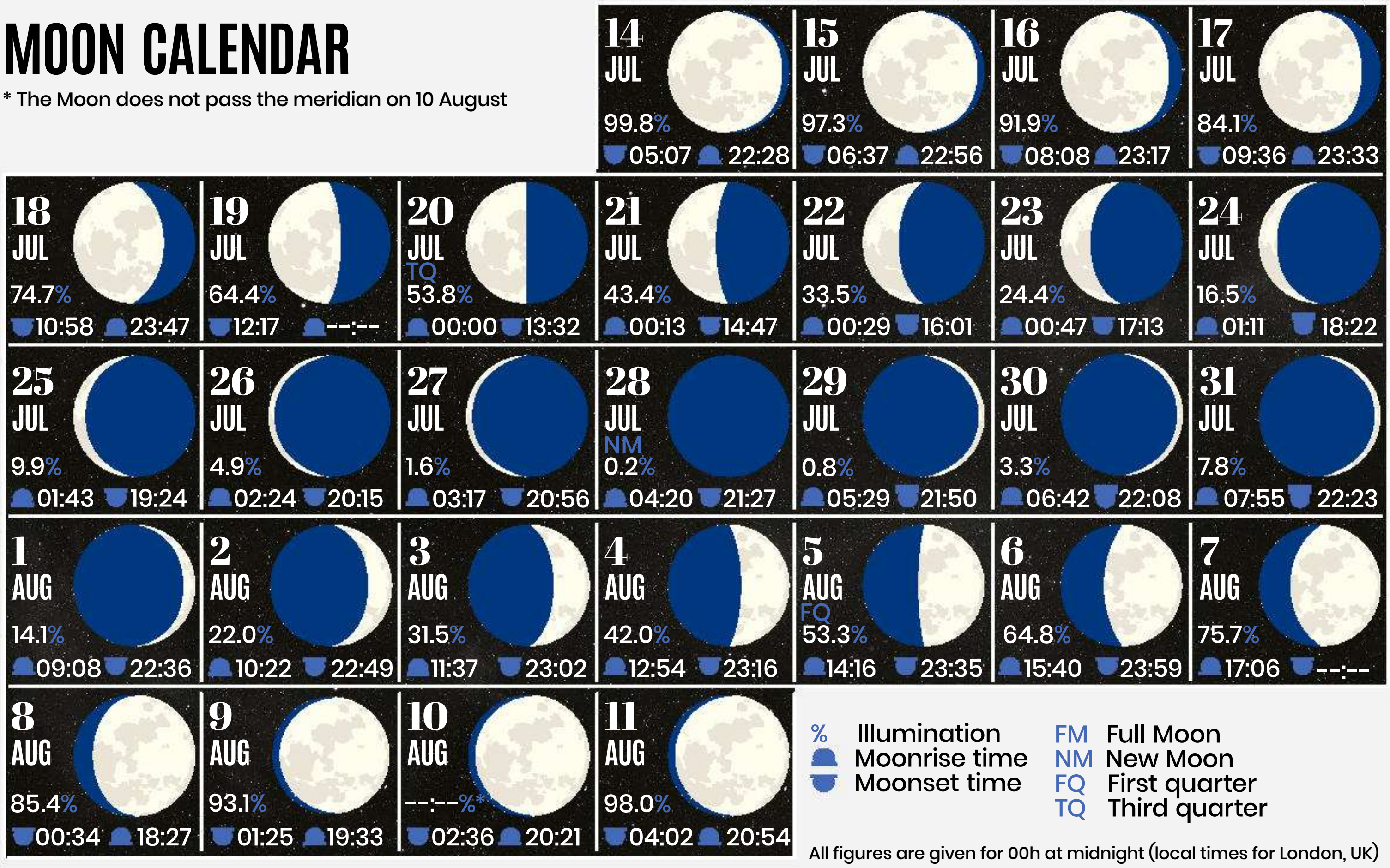
PLANETARIUM

28 JULY 2022


Lacerta
Cygnus
Auriga
Perseus
Triangulum
Andromeda
Gemini
VENUS
Aries
Pegasus
Delphinus
MARS
URANUS
Taurus
Orion
Canis Minor
Pisces
Equuleus
Monceros
JUPITER
ECLIPTIC
Cetus
NEPTUNE
SATURN
Canis Major
Aquarius
Eridanus
Capricornus
Fornax
Sculptor
Microscopium
Piscis Austrinus
Columba
Puppis
Caelum
Grus
MORNING SKY
OPPOSITION

MOON CALENDAR

* The Moon does not pass the meridian on 10 August



14 JUL
99.8%
◒05:07 ◓22:28

15 JUL
97.3%
◒06:37 ◓22:56

16 JUL
91.9%
◒08:08 ◓23:17

17 JUL
84.1%
◒09:36 ◓23:33

18 JUL
74.7%
◒10:58 ◓23:47

19 JUL
64.4%
◒12:17 ◓--:--

20 JUL
TQ
53.8%
◓00:00 ◒13:32

21 JUL
43.4%
◓00:13 ◒14:47

22 JUL
33.5%
◓00:29 ◒16:01

23 JUL
24.4%
◓00:47 ◒17:13

24 JUL
16.5%
◓01:11 ◒18:22

25 JUL
9.9%
◓01:43 ◒19:24

26 JUL
4.9%
◓02:24 ◒20:15

27 JUL
1.6%
◓03:17 ◒20:56

28 JUL
NM
0.2%
◓04:20 ◒21:27

29 JUL
0.8%
◓05:29 ◒21:50

30 JUL
3.3%
◓06:42 ◒22:08

31 JUL
7.8%
◓07:55 ◒22:23

1 AUG
14.1%
◓09:08 ◒22:36

2 AUG
22.0%
◓10:22 ◒22:49

3 AUG
31.5%
◓11:37 ◒23:02

4 AUG
42.0%
◓12:54 ◒23:16

5 AUG
FQ
53.3%
◓14:16 ◒23:35

6 AUG
64.8%
◓15:40 ◒23:59

7 AUG
75.7%
◓17:06 ◒--:--

8 AUG
85.4%
◒00:34 ◓18:27

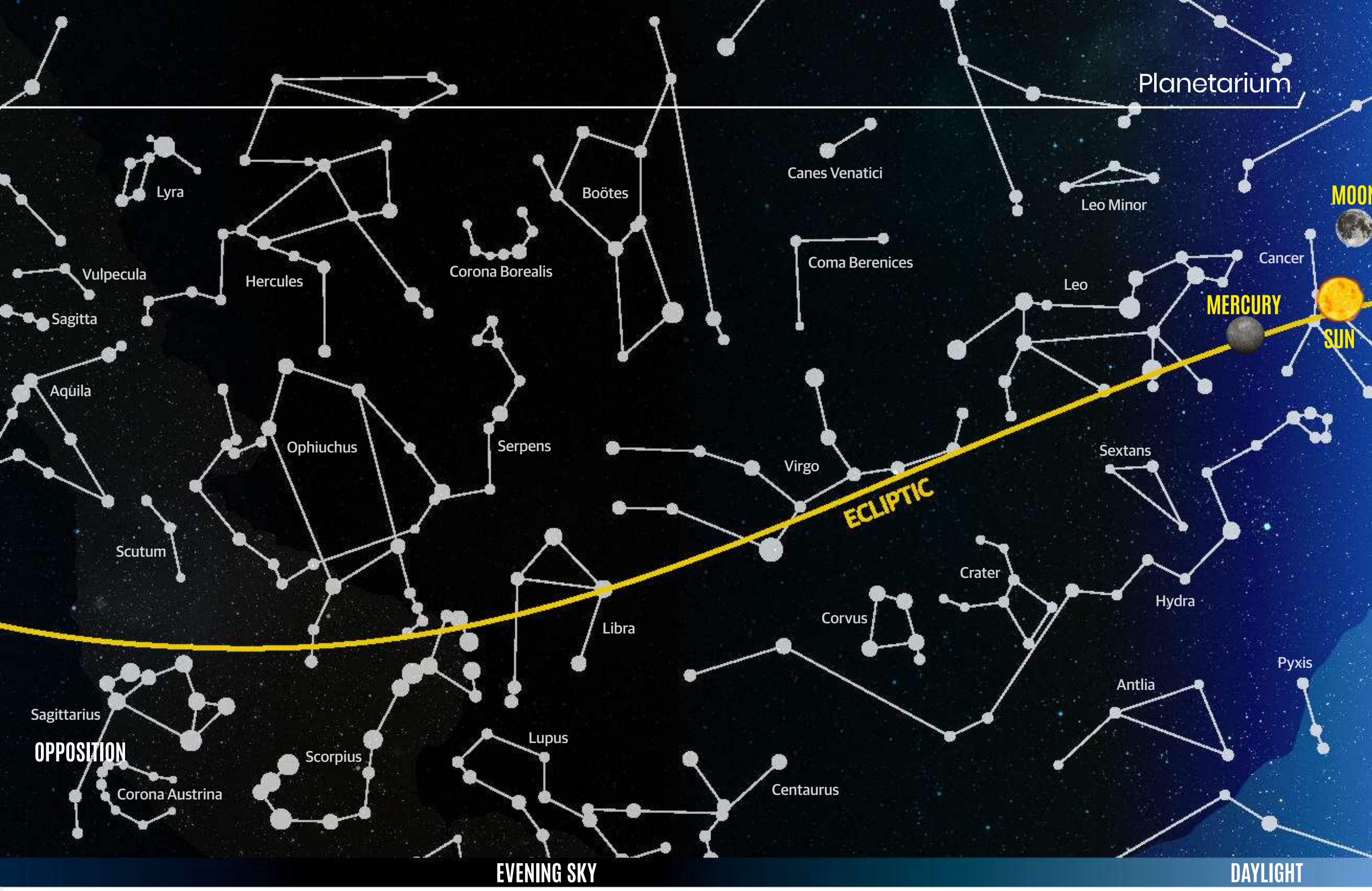
9 AUG
93.1%
◒01:25 ◓19:33

10 AUG
--:--%*
◒02:36 ◓20:21

11 AUG
98.0%
◒04:02 ◓20:54

%	Illumination	FM	Full Moon
◓	Moonrise time	NM	New Moon
◒	Moonset time	FQ	First quarter
		TQ	Third quarter

All figures are given for 00h at midnight (local times for London, UK)


Lyra
Boötes
Canes Venatici
Leo Minor
MOON
Vulpecula
Hercules
Corona Borealis
Coma Berenices
Cancer
Leo
MERCURY
SUN
Sagitta
Aquila
Ophiuchus
Serpens
Virgo
Sextans
ECLIPTIC
Scutum
Crater
Hydra
Corvus
Libra
Pyxis
Antlia
Sagittarius
OPPOSITION
Lupus
Scorpius
Corona Austrina
Centaurus
EVENING SKY
DAYLIGHT

ILLUMINATION PERCENTAGE

	21 JULY	28 JULY	5 AUGUST	12 AUGUST
MERCURY	100%	90%	80%	70%
VENUS	90%	90%	90%	90%
MARS	90%	80%	80%	80%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

PLANET POSITIONS

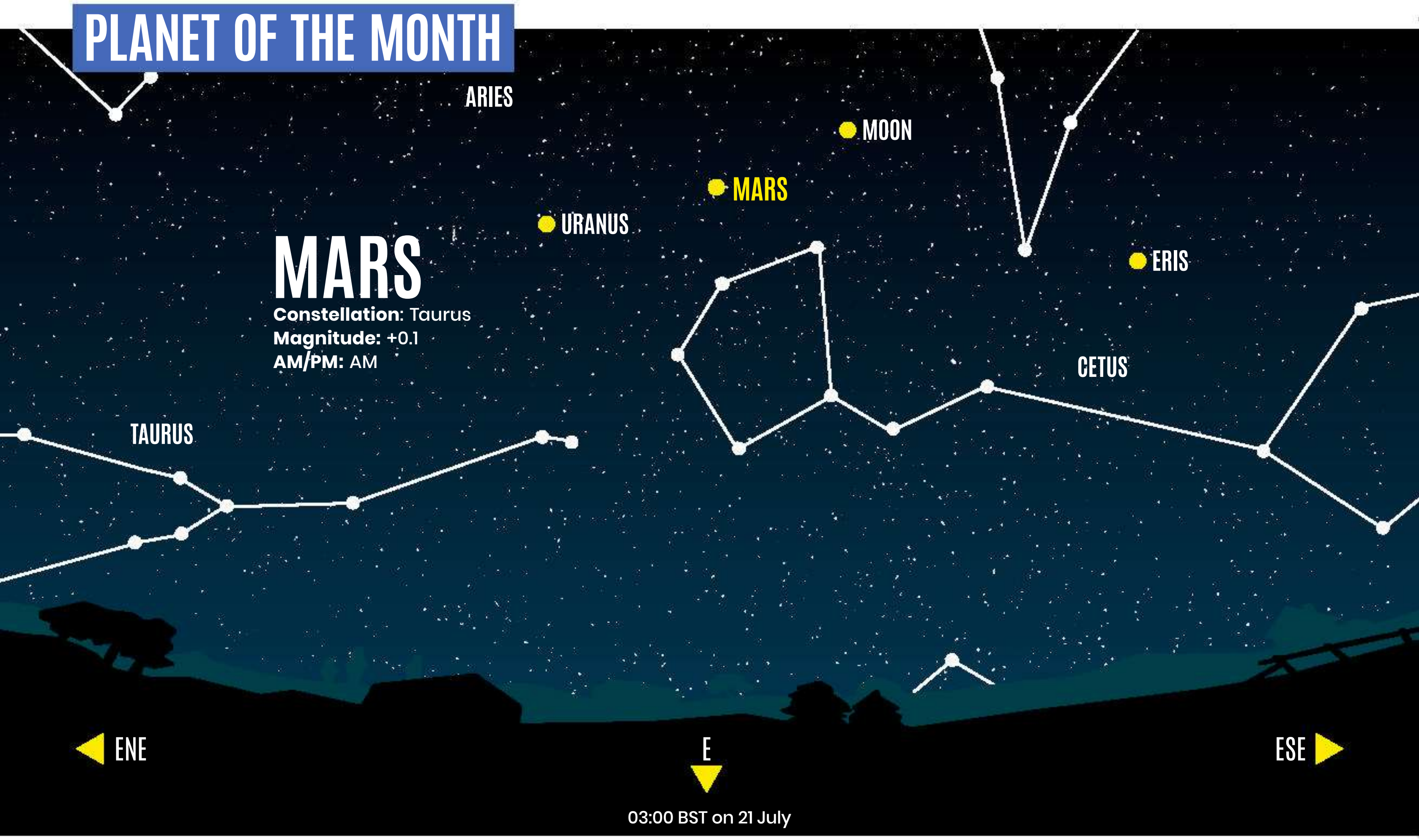
All rise and set times are given in BST

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
14 JULY	07h 18m 13s	+23° 28' 00"	Gemini	-2.0	04:31	21:06
21 JULY	08h 21m 55s	+21° 15' 05"	Cancer	-1.7	05:23	21:26
28 JULY	09h 18m 33s	+17° 27' 42"	Cancer	-0.9	06:16	21:31
5 AUG	10h 13m 16s	+12° 10' 09"	Leo	-0.4	07:10	21:24
12 AUG	10h 53m 30s	+07° 18' 06"	Leo	-0.1	07:48	21:10
14 JULY	05h 37m 26s	+22° 29' 09"	Taurus	-3.9	02:58	19:18
21 JULY	06h 14m 01s	+22° 51' 25"	Gemini	-3.9	03:04	19:30
28 JULY	06h 50m 48s	+22° 41' 49"	Gemini	-3.9	03:15	19:38
5 AUG	07h 32m 43s	+21° 51' 31"	Gemini	-3.9	03:31	19:42
12 AUG	08h 08m 57s	+20° 34' 10"	Cancer	-3.9	03:48	19:42
14 JULY	02h 16m 12s	+11° 45' 05"	Aries	+0.4	00:43	14:52
21 JULY	02h 34m 36s	+13° 18' 12"	Aries	+0.3	00:25	14:52
28 JULY	02h 52m 49s	+14° 44' 27"	Aries	+0.2	00:08	14:50
5 AUG	03h 13m 20s	+16° 14' 01"	Aries	+0.2	23:48	14:48
12 AUG	03h 30m 55s	+17° 24' 18"	Taurus	+ 0.1	23:31	14:45
14 JULY	00h 31m 41s	+01° 56' 43"	Cetus	-2.6	23:50	12:17
21 JULY	00h 32m 42s	+02° 00' 55"	Cetus	-2.6	23:23	11:51
28 JULY	00h 33m 07s	+02° 01' 22"	Cetus	-2.7	22:56	11:24
5 AUG	00h 32m 52s	+01° 57' 16"	Cetus	-2.7	22:25	10:52
12 AUG	00h 32m 02s	+01° 49' 41	Cetus	-2.8	21:57	10:23
14 JULY	21h 46m 02s	-14° 46' 02"	Capricornus	+0.5	22:32	08:05
21 JULY	21h 44m 25s	-14° 55' 21"	Capricornus	+0.4	22:03	07:35
28 JULY	21h 42m 37s	-15° 05' 25"	Capricornus	+0.4	21:35	07:05
5 AUG	21h 40m 24s	-15° 17' 29"	Capricornus	+0.3	21:03	06:30
12 AUG	21h 38m 23s	-15° 28' 15"	Capricornus	+0.3	20:34	05:59

THIS MONTH'S PLANETS

Mars is excellent viewing this month, while the majority of the outer planets take the morning watch

PLANET OF THE MONTH



MARS

Constellation: Taurus
Magnitude: +0.1
AM/PM: AM

03:00 BST on 21 July

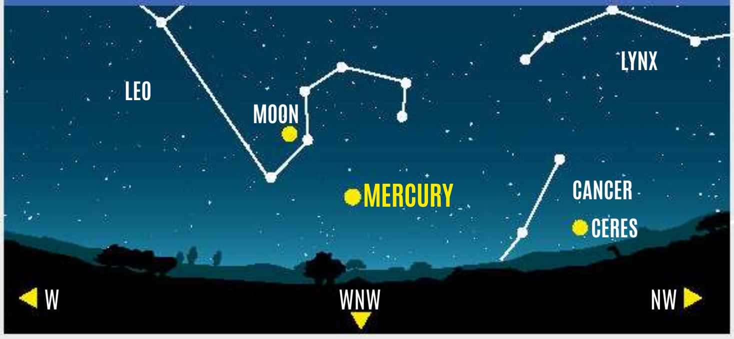
This will be a good month for you if you enjoy seeing the Red Planet. It will be found in the rather star-starved constellation of Aries, rising around four hours before the Sun. At that time Mars will be shining with a magnitude of +0.4, making it quite striking to the naked eye, especially with its distinctive orange hue. As the days pass Mars will increase in brightness, making it appear even more obvious. Look out for a waning crescent Moon shining to the planet's lower right on the morning of 21 July, and to its lower left the following morning.

Mars' rise in brightness will continue relentlessly during the month. By 1 August Mars will have reached magnitude +0.2, and by the end of our observing period it will have drifted into Taurus and will be shining at an impressive magnitude of +0.1, making it brighter than Aldebaran, the brightest star in Taurus. By then Mars will be very obvious to the naked eye, and while they won't be able to show you its disc, binoculars will really enhance the planet's brightness and its orange-pink colour. But Mars is still so far away that even if you have a small telescope it will struggle to show you Mars as a world; its ruddy disc will appear so small in the eyepiece it will be only roughly the same size as one of the Moon's smallest craters seen at the same magnification.

As impressive as Mars will be this month, it will be much more striking at the end of the year. In December it will be much closer to Earth than it is now. It will rise as the Sun sets and will be a stunning object all through the night, magnitude -1.9 at its brightest. At that time even a small telescope will show its disc well, and large telescopes will offer wonderful views of its bright ice caps and dark features on its surface.

If you can't wait until December to see features on Mars, all you have to do is go to the websites of NASA's Mars rovers, Curiosity and Perseverance. There you'll find links to whole galleries of thousands of wonderful images sent back by the rovers, showing epic, sweeping Martian vistas and close-ups of the ancient rocks and stones that cover its surface.

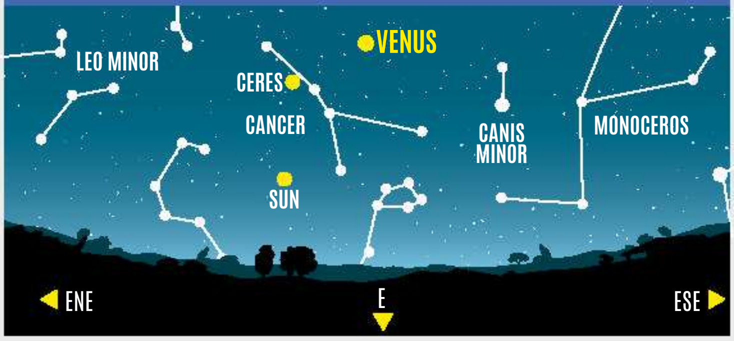
MERCURY 21:00 BST on 30 July


LEO
MOON
LYNX
MERCURY
CANCER
CERES
W
WNW
NW

Constellation: Gemini **Magnitude:** -0.1 **AM/PM:** PM

At the start of our observing period Mercury, the closest world to the Sun, is technically a 'morning star', but it will be so close to the Sun in the sky it is unlikely to be visible. By late July Mercury will have moved up into the evening sky, looking like a faint star low in the northwest during twilight.

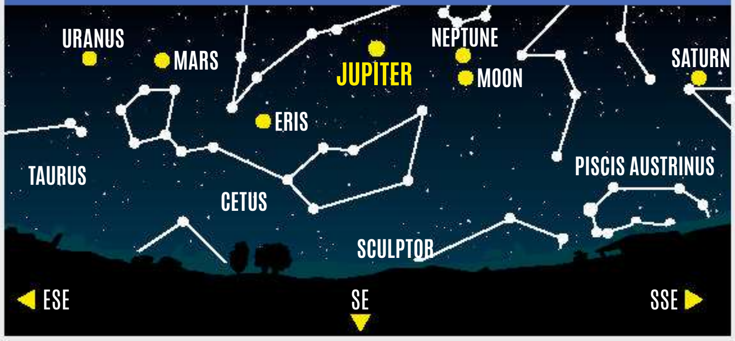
VENUS 07:00 BST on 11 August


LEO MINOR
CERES
VENUS
CANCER
CANIS MINOR
MONOCEROS
SUN
ENE
E
ESE

Constellation: Taurus **Magnitude:** -3.9 **AM/PM:** AM

Venus will be clearly visible to the naked eye as a bright 'star' in the east as the sky brightens with the approach of dawn. On the morning of 14 July Venus will rise two hours before the Sun and will be less than a degree away from Messier 1, the Crab Nebula, the ghostly remains of an exploded star.

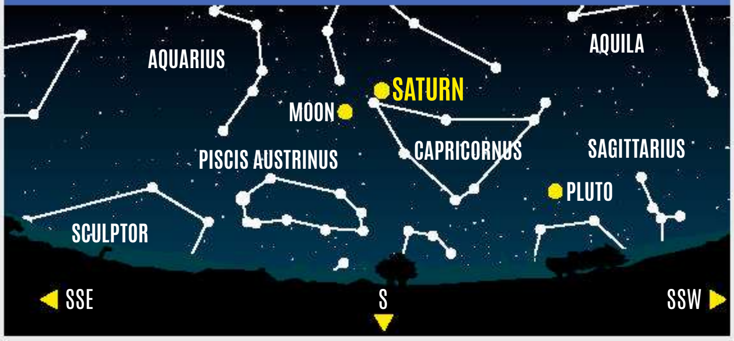
JUPITER 04:00 BST on 18 July


URANUS
MARS
JUPITER
NEPTUNE
MOON
SATURN
ERIS
TAURUS
CETUS
PISCIS AUSTRINUS
SCULPTOR
ESE
SE
SSE

Constellation: Cetus **Magnitude:** -2.5 **AM/PM:** AM

Jupiter will be clearly visible to the naked eye during the month ahead, looking like a bright blue-white 'star' in the sky. At the start of our observing period it will rise at midnight and will then be visible until dawn. Between 18 and 20 July the waning Moon will approach and then pass beneath Jupiter.

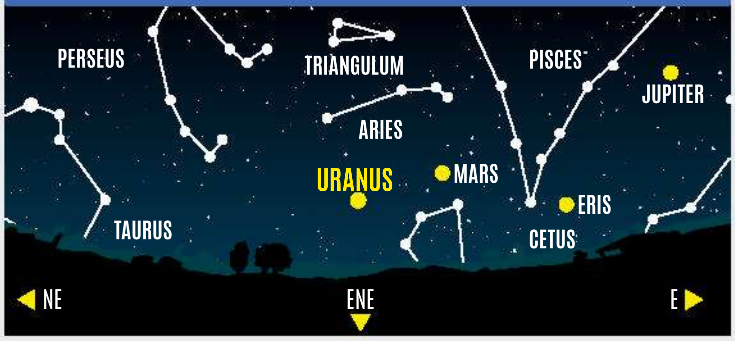
SATURN 04:00 BST on 16 July


AQUARIUS
AQUILA
SATURN
MOON
PISCIS AUSTRINUS
CAPRICORNUS
SAGITTARIUS
PLUTO
SCULPTOR
SSE
S
SSW

Constellation: Capricornus **Magnitude:** +0.5 **AM/PM:** PM

During the month ahead Saturn will be visible to the naked eye as a yellow-hued star, shining to the right of much brighter, bluer Jupiter. At the start of our observing period it will be rising at around 23:00, making it an evening object, and it will be visible all through the night until the sky brightens with the approach of dawn.

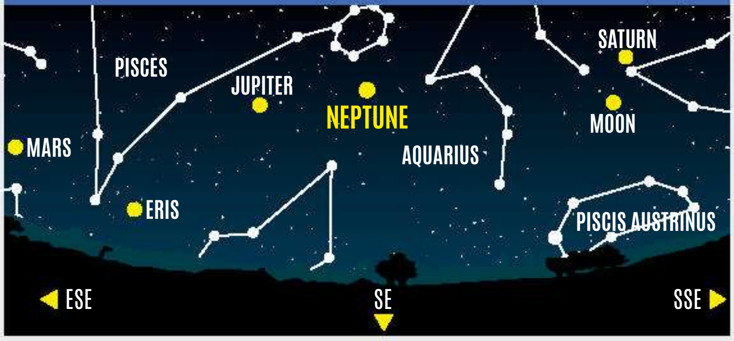
URANUS 02:00 BST on 16 July


PERSEUS
TRIANGULUM
PISCES
JUPITER
ARIES
URANUS
MARS
ERIS
TAURUS
CETUS
NE
ENE
E

Constellation: Aries **Magnitude:** +5.8 **AM/PM:** AM

Uranus will be a faint morning star. On the morning of 3 August Uranus will be only a degree-and-a-half away from Mars, shining directly above it, so the two planets will be in the same field of view in binoculars and small telescopes. Uranus will look like a faint, pale-green star above much brighter orange-hued Mars.

NEPTUNE 02:00 BST on 16 July


SATURN
PISCES
JUPITER
NEPTUNE
MARS
AQUARIUS
MOON
ERIS
PISCIS AUSTRINUS
ESE
SE
SSE

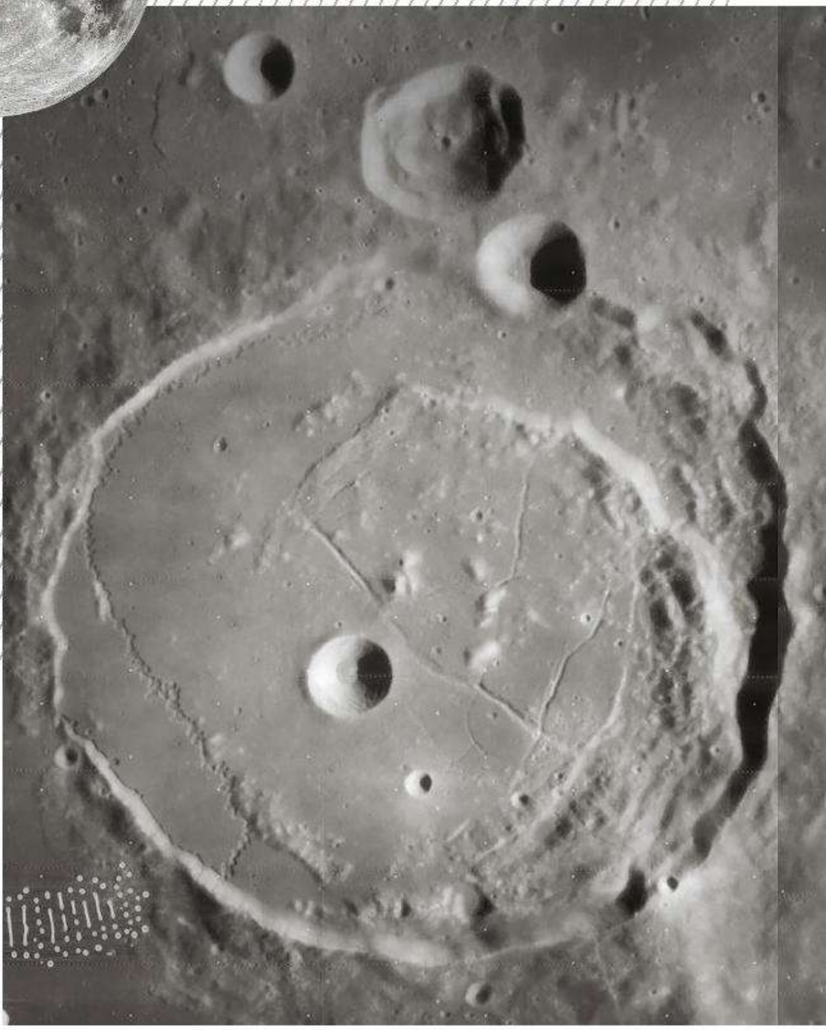
Constellation: Pisces **Magnitude:** +7.9 **AM/PM:** AM

Neptune is a very faint object. You'll find it on the edge of the constellation of Pisces, close to the border with Aquarius, and 13 degrees away from bright Jupiter. Through a telescope Neptune looks like a faint star, but your eye might just detect its blue-green hue if you look at it during the darkest part of the night.

MOON TOUR

POSIDONIUS CRATER

This impact makes for prime viewing this month



© NASA

TOP TIP!

Posidonius is an ideal target on the morning of 24 July under good seeing conditions due to a good lunar elevation. A Moon filter will improve contrast, toning down any glare that often washes out intricate features.

One of the Moon's most sublime and recognisable craters, Posidonius can be viewed to good advantage as it's illuminated by a local evening Sun on the morning of 4 August, when the Moon is situated above the southeastern horizon. Two weeks later, the Moon lies low above the western horizon as the dusk skies are darkening, but vigilant telescopic observers may still be able to make out Posidonius near the lunar terminator despite the Moon's low twilight altitude.

Measuring 95 kilometres (59 miles) across, Posidonius is a prominent crater that lies at the northeastern border of the large near-circular Mare Serenitatis (Sea of Serenity) and at the entrance to Lacus Somniorum (Lake of Dreams), an irregular lava-filled plain that forms a short arc parallel to the northeastern shoreline of Mare Serenitatis. When illuminated, Posidonius is easily identified through small instruments, even steadily mounted 7x50 binoculars.

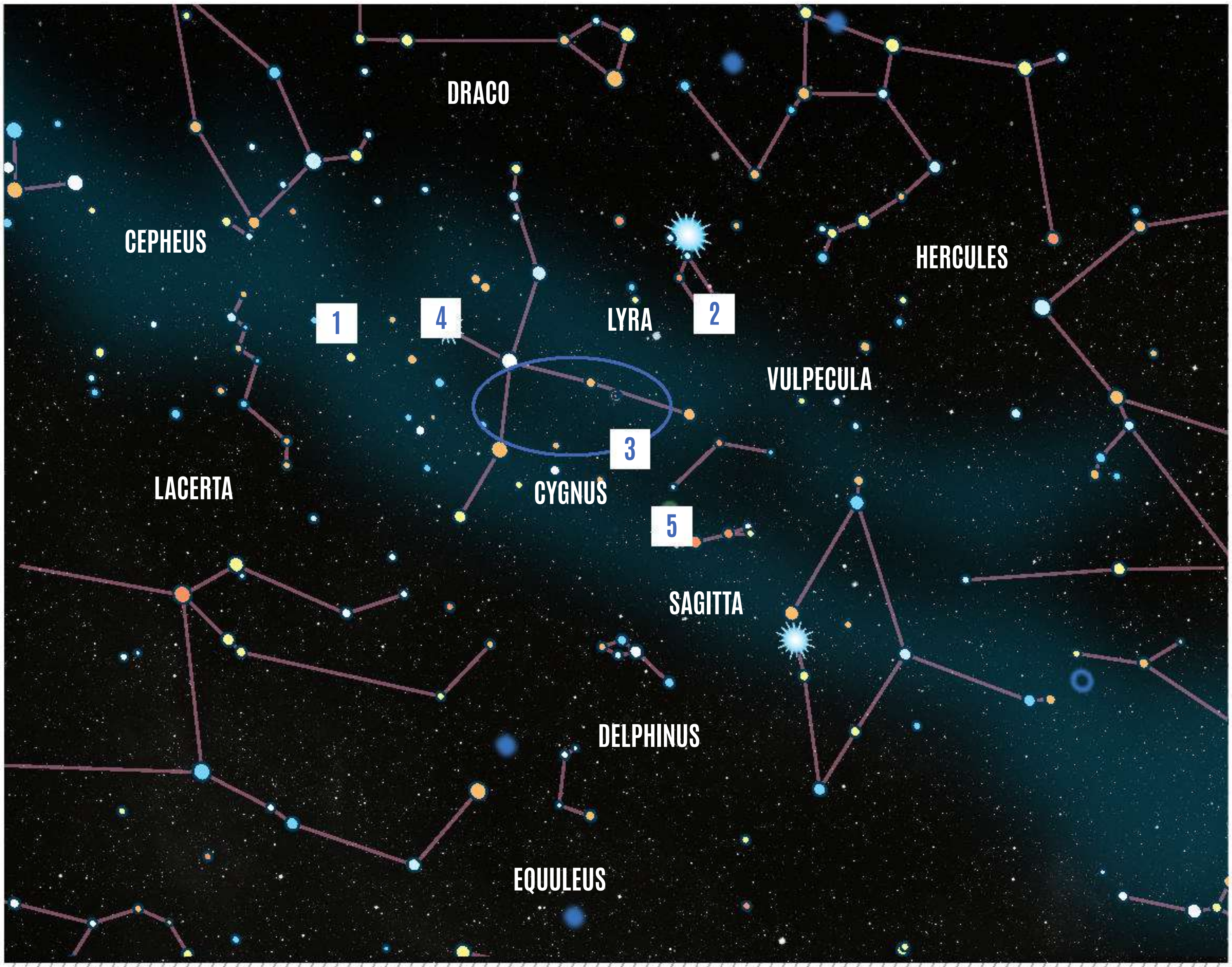
However, the complex nature of Posidonius is only revealed under good seeing conditions through telescopes larger than 80mm at magnifications higher than 50x. Most noticeable is the fact that the southern rim of Posidonius is joined with the disintegrated crater Chacornac. While both Posidonius and Chacornac are asteroid impact craters, the more eroded topography of Chacornac suggests that it predates the formation of Posidonius by several hundred million years.

Both craters are thought to have formed after the Serenitatis basin, as their outlines appear impressed over the basin's outline and both are filled with Serenitatis lava flows. Chacornac is likely to have been formed some time before the nearby Imbrium basin was formed, while Posidonius is thought to have been formed shortly after the Imbrium basin impact around 3.8 billion years ago – one of the final episodes of the Late Heavy Bombardment, when the inner Solar System was a veritable cosmic shooting gallery of asteroids and other debris from the formation of the planets.

Posidonius is one of the Moon's more unusual large carters, possessing a low but complete and clear-cut rim, the north and northeastern parts of which are overlain by numerous smaller craters, Posidonius J, B and D. No traces of the initial external impact remain visible because of later lava flooding in Mare Serenitatis and Lacus Somniorum. The interior of Posidonius presents a variety of complexity, though visibility is dependent on seeing conditions and the instrument and magnification used. A prominent bowl-shaped crater, Posidonius A, sits slightly west of the floor centre at 12 kilometres (74 miles) wide – this is easily seen through small instruments.

East of Posidonius A there are a number of small valleys – the linear rilles of Rimae Posidonius, the most prominent of which cuts 50 kilometres (31 miles) across the centre of the floor and is cut across itself at a right angle by a smaller rille. Another longer rille makes its way along the floor near the inner western wall. The best views of Rimae Posidonius are obtained through a six-inch telescope at high magnification. A prominent curving ridge crosses the eastern part of Posidonius' floor – a huge block of crust appears to have slipped away from the main eastern wall.

Chacornac appears much more irregular than Posidonius, with a crustal imprint that's obviously less fresh. Like Posidonius, it has an eastern central crater named Chacornac A and several rilles that run northwest to southeast across its floor – easily visible through a six-inch telescope at high power and under a low illumination. Together, Posidonius and Chacornac present a highly interesting lunar sight when illuminated.



NAKED EYE AND BINOCULAR TARGETS

See a cloud of stars and shells of gas produced by faraway dying suns

1 Messier 39

Messier 39 is a large open star cluster. It's seven light years across and 824 light years from Earth. It contains around 30 stars. At magnitude +5.5, it's visible to the naked eye as a Moon-sized faint smudge in a dark sky. Binoculars will show its triangular shape.

2 The Ring Nebula (Messier 57)

The Ring Nebula is so faint at magnitude +8.8 that you will need binoculars to see it. Even then it will just look like a tiny out-of-focus star. It is actually a shell of glowing gases puffed out by a dying star over 2,000 light years away.

3 Cygnus X

Down the right side of the Northern Cross, which forms part of the constellation of Cygnus, you will see a long, fuzzy area. This is the Cygnus X star cloud. Binoculars reveal it is made of countless millions of faint stars – our view down a neighbouring spiral arm in our galaxy.

4 Deneb (Alpha Cygni)

The brightest star in Cygnus, but only the 19th-brightest star in the sky, Deneb is a blue supergiant so huge it would swallow Earth if put in the Sun's place. It's around 2,600 light years away and is roughly 20,000 times more luminous than our own Sun.

5 The Dumbbell Nebula (Messier 27)

The Dumbbell Nebula can be seen with binoculars as a very small, smudgy spot. It's 1,360 light years away, and like Messier 57 it's a ghostly shell of material expelled from a star in the last stages of its life.

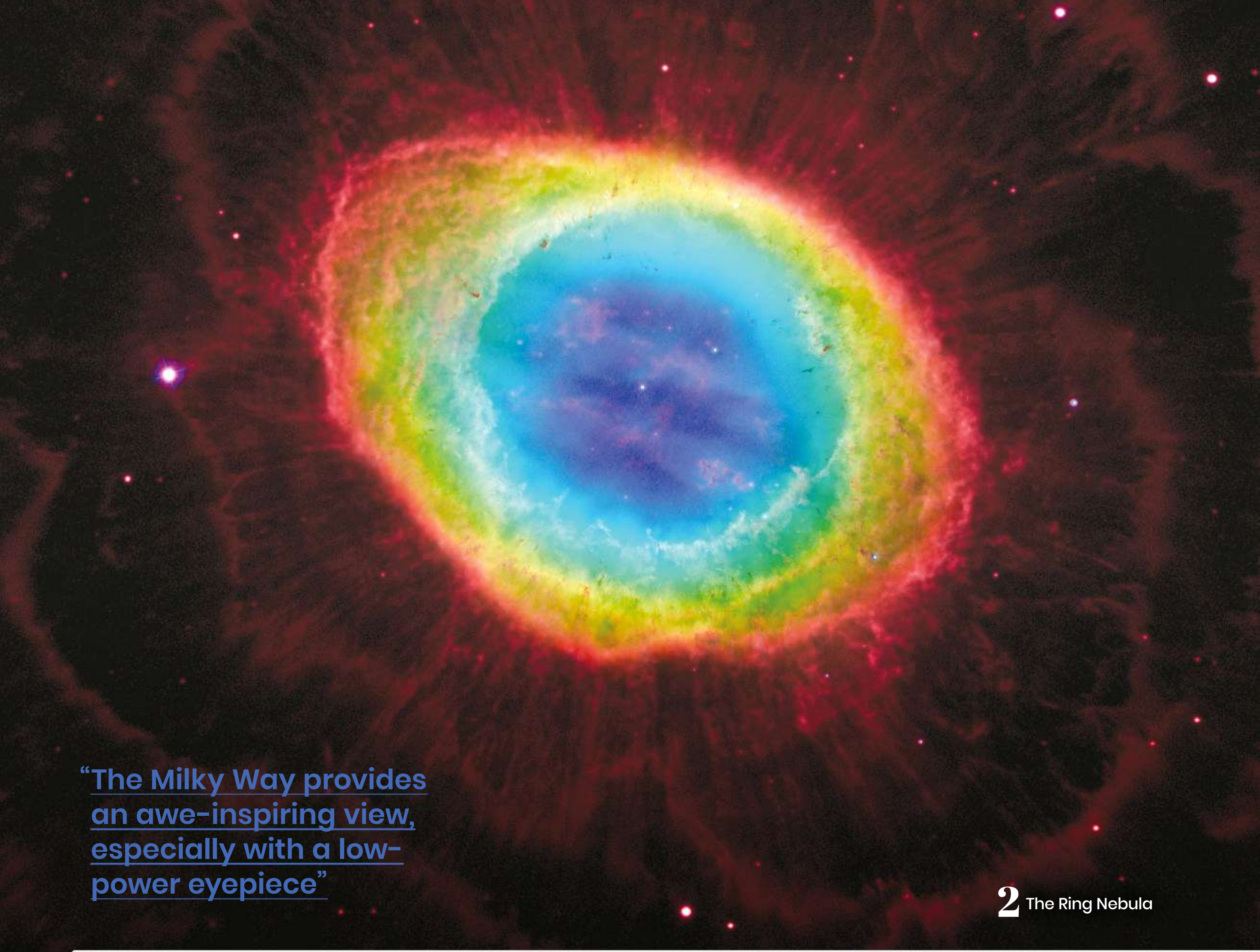
DEEP SKY CHALLENGE

GEMS OF THE SWAN AND THE HARP

The summer skies are full of deep-sky objects to point your telescope at

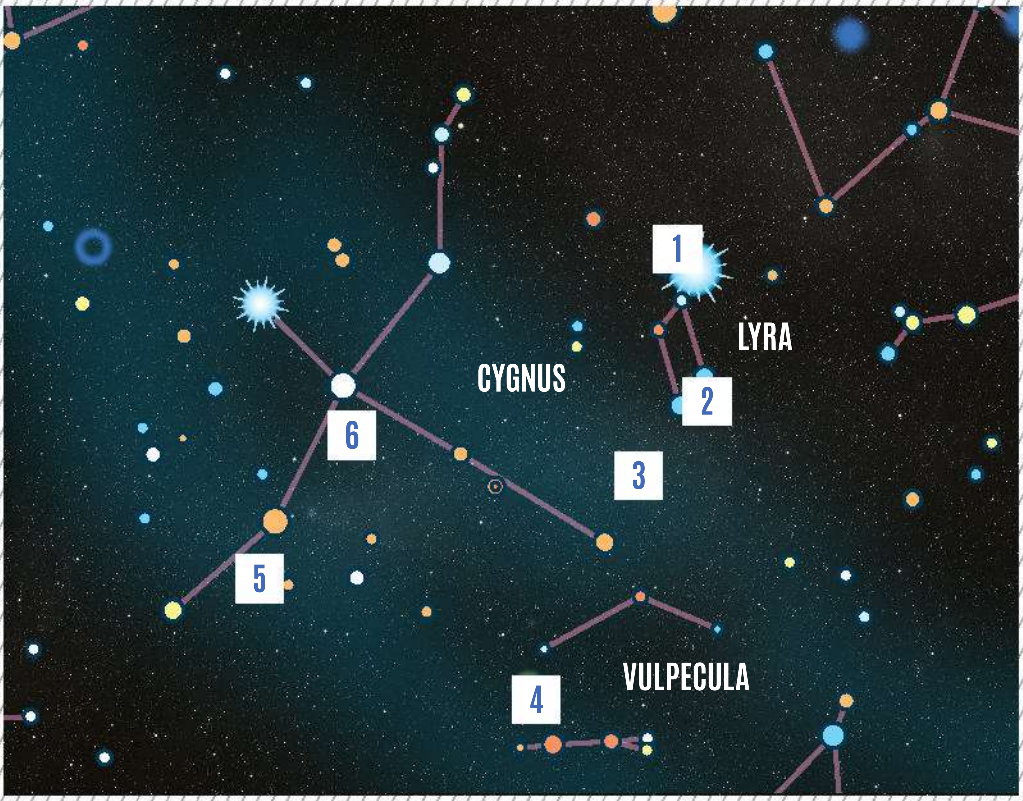
With the Milky Way arching across the sky at this time of year, the constellations that are located within it or straddle its borders are littered with amazing objects towards which you can turn your telescope and feast your eyes. There are double stars, open star clusters, globular star clusters and nebulae in and around the region of sky dominated by the familiar constellation of Cygnus (the Swan) and Lyra (the Harp).

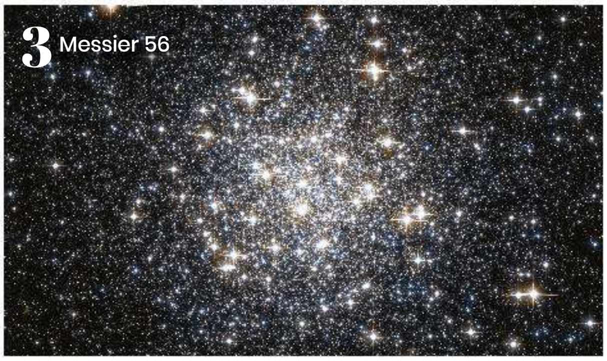
The constellation of Lyra plays host to two intriguing objects, namely the double-double stars of Epsilon Lyra and the famous Ring Nebula (Messier 57), while Cygnus is peppered with open star clusters and nebulae. The Milky Way provides an awe-inspiring view, especially with a low-power eyepiece. You can just cruise through it and enjoy the view, but if you are looking for something more substantial, here are a few of the best objects for your telescope.



> "The Milky Way provides an awe-inspiring view, especially with a low-power eyepiece"

2 The Ring Nebula




3 Messier 56

4 The Dumbbell Nebula

5 Veil Nebula

1 Epsilon Lyrae

Epsilon Lyrae is a star system when observed under magnification, even under light-polluted skies. The larger your aperture, the more components you'll be able to split the binary into – a six-inch instrument will be able to resolve two pairs of off-white stars.

2 Ring Nebula

A three-inch telescope will reveal an elongated hazy spot, while six inches will pick out the ring structure. Larger instruments will reveal a faint central star. Some observers report spotting a greenish tint, but you'll need filters to admire its full glory.

3 Messier 56

An eight-inch aperture will resolve this tightly packed globular cluster into a fuzzy patch. In order to resolve it into its individual stellar components, you'll need an eight-inch instrument or larger. The brightest stars within the cluster are of magnitude +13.

4 The Dumbbell Nebula

At magnitude +7.4, the Dumbbell Nebula (Messier 27) can be detected using binoculars with magnifications of at least 10x50, but in order to achieve more detail you will need at least a small telescope.

5 Veil Nebula

The Veil Nebula is the expelled remnants of a supernova. There are two bright regions in the nebula that can be seen through binoculars from a sufficiently dark site, but to see its eastern and western portions you'll require a telescope with an aperture of six to eight inches.

6 Messier 29

This open cluster looks best at a low power. With a magnitude of +7.1, it's relatively small, occupying an area of sky of about seven arcminutes. It's shape is visible in a telescope of about three inches.

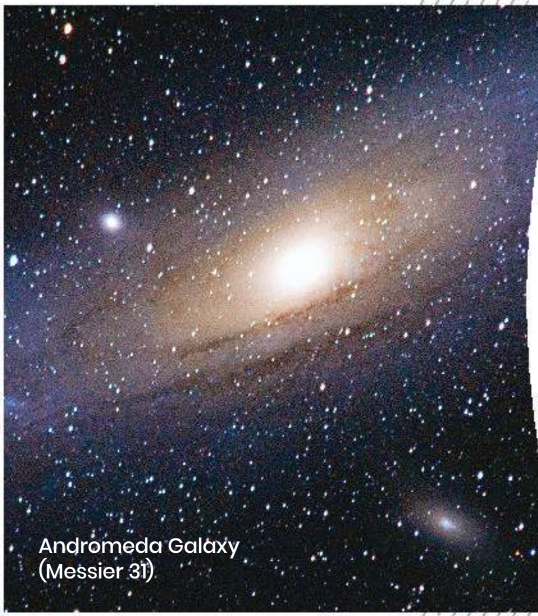
© NASA; STScI; ESA; Ken Crawford

THE NORTHERN HEMISPHERE

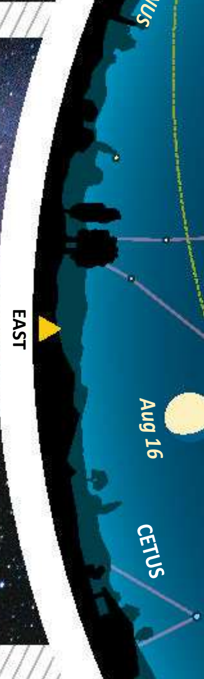
Summer skies are alive with star clusters and a smattering of galaxies

In mid-July and heading into August, the summer skies still offer a lot in the way of deep-sky objects for astronomers who enjoy observing the night sky in the late evening and into the small hours. As well as the nebulae of summer, the star clusters of Cygnus, Hercules and low-on-the-horizon Ophiuchus and the galaxies of Ursa Major are excellent pickings for observers with binoculars or telescopes. August in particular is an ideal time to observe our nearest spiral galaxy, Andromeda. Star clusters NGC 884, NGC 7686 and NGC 1502, of Perseus, Andromeda and Camelopardalis respectively, are good targets in the early hours of the morning.

Kemble's Cascade asterism in Camelopardalis



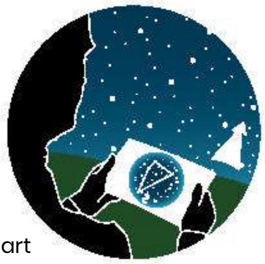
Andromeda Galaxy (Messier 31)



Messier 13

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.



1 Hold the chart above your head with the bottom of the page in front of you.

2 Face south and notice that north on the chart is behind you.

3 The constellations on the chart should now match what you see in the sky.

MAGNITUDES

Magnitudes

- ✹ Sirius (-1.4)
- ✹ -0.5 to 0.0
- ✹ 0.0 to +0.5
- ✹ +0.5 to +1.0
- ✹ +1.0 to +1.5
- ○ +1.5 to +2.0
- ○ +2.0 to +2.5
- ○ +2.5 to +3.0
- ○ +3.0 to +3.5
- ○ +3.5 to +4.0
- ○ +4.0 to +4.5
- • Fainter
- ● Variable star

SPECTRAL TYPES

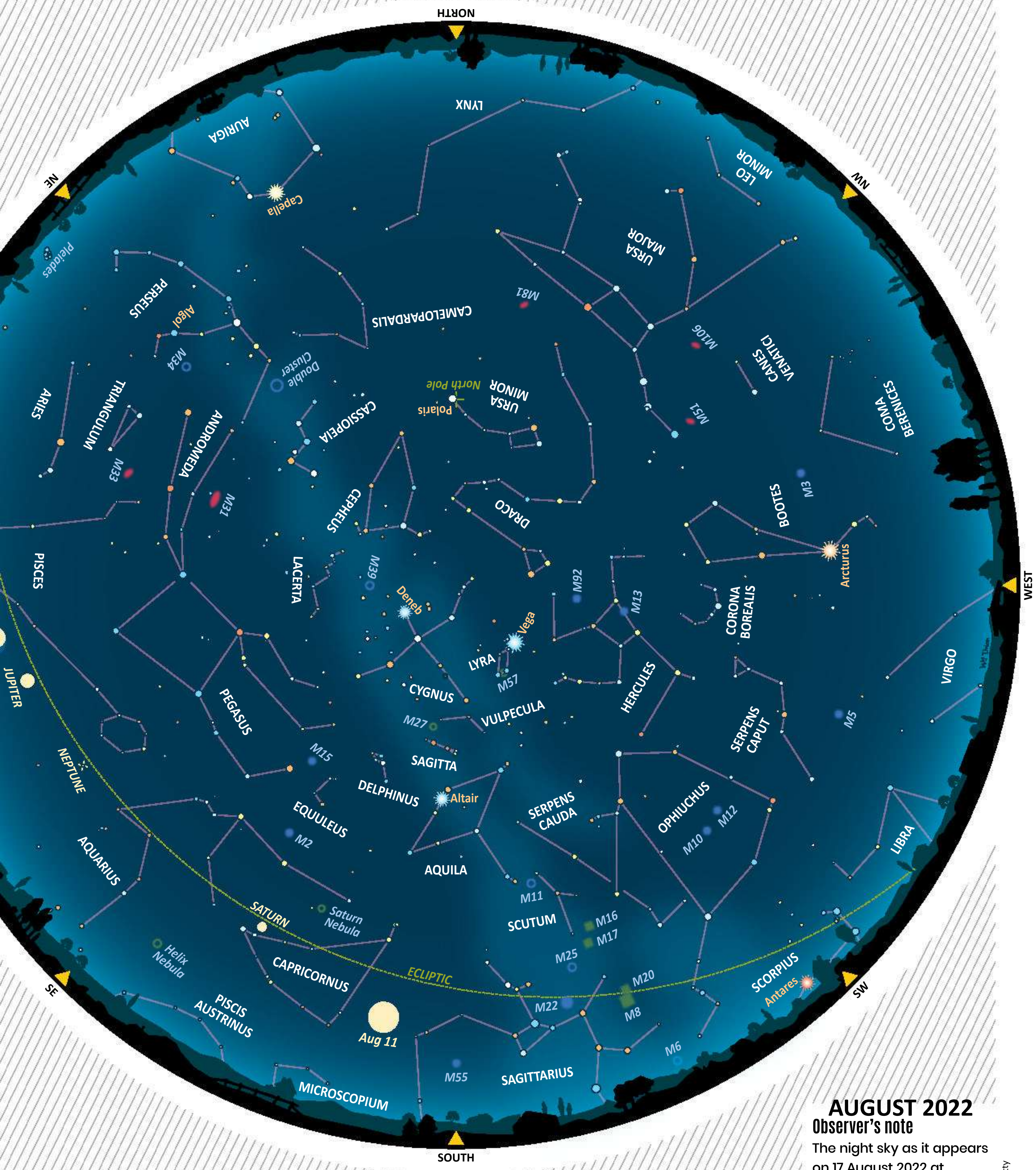
Spectral types

- ✹ ● O-B
- ✹ ○ A
- ✹ ○ F
- ✹ ● G
- ✹ ● K
- ✹ ● M

DEEPSKY OBJECT

Deep-sky objects

- ○ ○ Open star clusters
- ● ● Globular star clusters
- ■ ■ Bright diffuse nebulae
- ○ ○ Planetary nebulae
- ⬮ ⬮ Galaxies


NORTH
NE
NW
WEST
SE
SW
SOUTH
LYNX
AURIGA
Capella
LEO MINOR
URSA MAJOR
Pleiades
PERSEUS
Algol
M34
Double Cluster
CAMELOPARDALIS
M81
M106
CANES VENATICI
North Pole
Polaris
URSA MINOR
M51
COMA BERENICES
ARIES
TRIANGULUM
M33
ANDROMEDA
M31
CASSIOPEIA
CEPHEUS
DRACO
BOOTES
M3
Arcturus
PISCES
LACERTA
M39
Deneb
M92
M13
CORONA BOREALIS
Vega
LYRA
M57
HERCULES
VIRGO
JUPITER
PEGASUS
CYGNUS
VULPECULA
M27
SERPENS CAPUT
M5
NEPTUNE
M15
SAGITTA
DELPHINUS
Altair
SERPENS CAUDA
OPHIUCHUS
M12
M10
LIBRA
EQUULEUS
M2
AQUARIUS
AQUILA
M11
SATURN
Saturn Nebula
SCUTUM
M16
M17
Helix Nebula
CAPRICORNUS
M25
ECLIPTIC
M20
SCORPIUS
Antares
PISCIS AUSTRINUS
M22
M8
Aug 11
M6
M55
SAGITTARIUS
MICROSCOPIUM

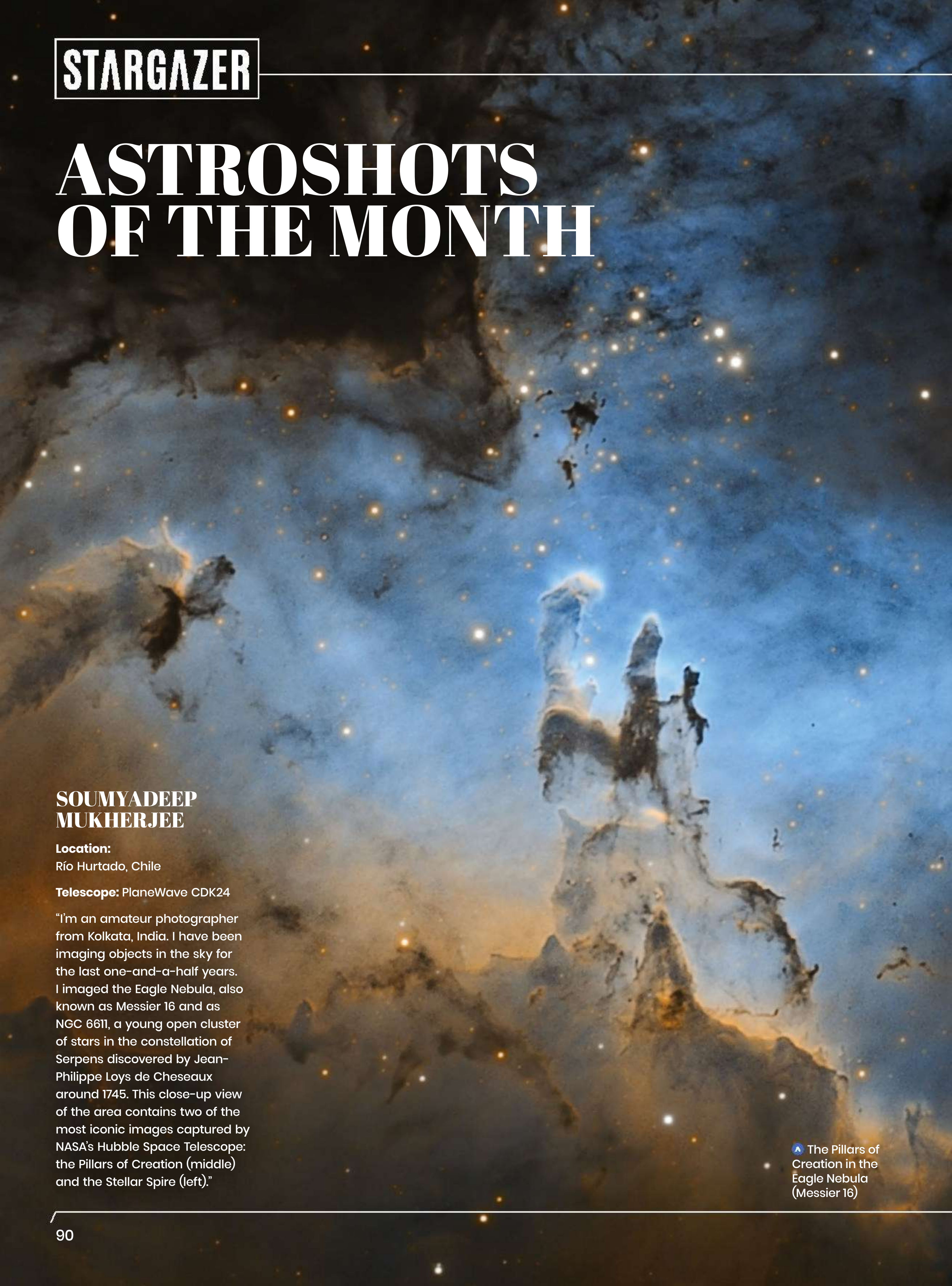
AUGUST 2022

Observer's note

The night sky as it appears on 17 August 2022 at approximately 22:00 (BST)

© Getty

ASTROSHOTS OF THE MONTH



SOUMYADEEP MUKHERJEE

Location:
Río Hurtado, Chile

Telescope: PlaneWave CDK24

"I'm an amateur photographer from Kolkata, India. I have been imaging objects in the sky for the last one-and-a-half years. I imaged the Eagle Nebula, also known as Messier 16 and as NGC 6611, a young open cluster of stars in the constellation of Serpens discovered by Jean-Philippe Loys de Cheseaux around 1745. This close-up view of the area contains two of the most iconic images captured by NASA's Hubble Space Telescope: the Pillars of Creation (middle) and the Stellar Spire (left)."

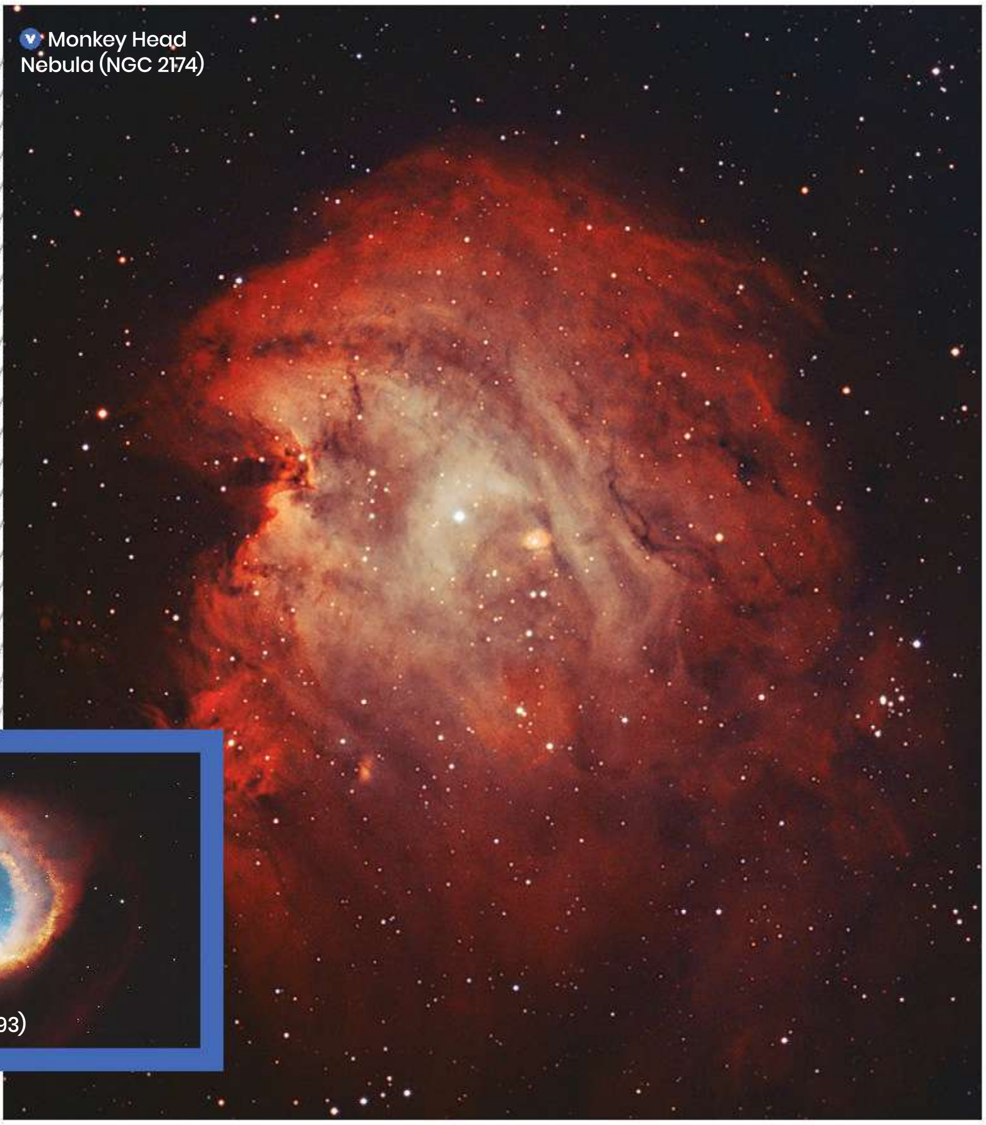
A The Pillars of Creation in the Eagle Nebula (Messier 16)

STEVE COATES

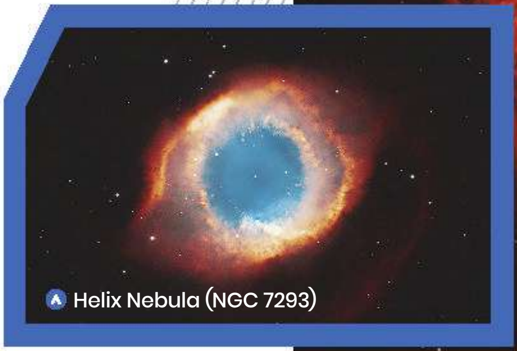
Location: Ocala, Florida

Telescope: Explore Scientific ED 127 APO

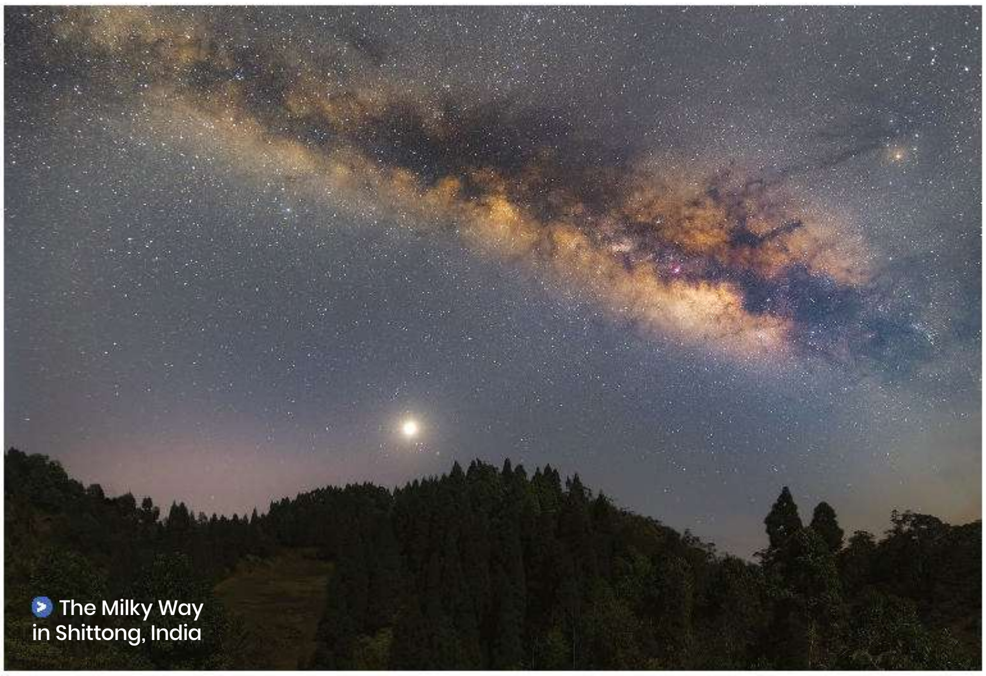
"It was after I bought my first telescope back in 2010 that I began pursuing my hobby in astrophotography. Before I made my purchase, I'd never even looked through a telescope and had never really taken photographs. I always enjoyed looking at images in astronomy magazines, as well as those taken by Hubble, and was keen to recreate something similar. I learned how to shoot and process my images of the night sky by scrolling through websites for advice, as well as through much trial and error. At first I was pleased with my images of Solar System targets, but I quickly found myself photographing objects such as galaxies and nebulae with great success."



Monkey Head Nebula (NGC 2174)



Helix Nebula (NGC 7293)



The Milky Way in Shittong, India

BASUDEB CHAKRABARTI

Location: West Bengal, India

"It's my passion to take pictures of the night sky and engulf its beauty through my lenses. North Bengal is one of those places where I exercise my passion on a frequent basis. I went to a place called Namthing Pokhri to capture the Milky Way. Although all the water in the lake is dried up at this time of year, the place was beautiful. I knew that the Milky Way would go up over the pine forest by the lake, so I decided to come here at night."

APP REVIEW

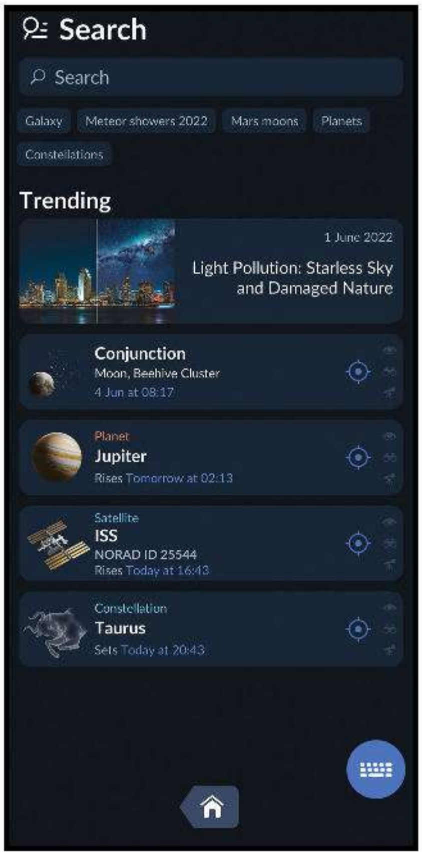
SKY TONIGHT

Tour the night sky with this handy app, an essential piece of kit for seamless navigation

Reviewed by Ian Evenden

Sky Tonight comes from Vito Technology, the same company which brought us Star Walk 2, and like that app it provides a view of the night sky and the wonders you can see in it. At first glance, you'd be forgiven for wondering whether someone had slipped up and accidentally released the same app twice. They both depict the night sky, both allow you to raise your camera to the heavens to identify something and both let you look up information on what you're looking at.

So what's the difference? Sky Tonight is more focused on the identification of objects than on visual effects and 3D models. It brings together a lot of disparate information in one place and can predict your likely chances of success on a stargazing expedition based on weather and light pollution, as well as the phase of the Moon and time of sunset.



The app can show what to look out for on a certain night

The other half of the app concentrates on what you can see, bringing the bright stars and planets into sharp focus with lots of information about their history, lore and the times they'll rise over the horizon over the next month. It even tips you off about events such as conjunctions and occultations. In brief, it's one of the best stargazing apps currently available. The app's home page is its map. It uses your location to display the stars as you see them in real time. Hold your device up, move it around and it will move too, showing you the stars in whichever direction you choose, both above and below the horizon.

Tap the compass button in the bottom right and the motion tracking is disabled so you can pan the map around with your finger. This mode makes it easier to zoom into the map to an object that interests you, tapping on it to bring up information such as distance, brightness and any lore attached to it. Tap the icon again when it looks like a camera aperture and your device's camera is activated, allowing you to point it at a bright point in the night sky to identify it.

This basic functionality is supremely easy to use. It's also duplicated elsewhere, in apps such as Google Sky Map and the developer's own Star Walk 2. The white-on-blue map – though there's a redder night mode – and minimalist artwork show the night sky extremely well, and it's easy to spend time watching satellites drift across the points of the constellations or hunting out the objects with interesting stories attached to them. To go deeper into the app, you need to use one of four icons displayed along the bottom edge of the map, just above the location information: a magnifying glass, telescope, calendar and three lines.

The magnifying glass opens up the search functionality, but its page is much more than just a box to be typed into. There's trending information about recent astronomical phenomena – things like the most recent meteor showers and conjunctions. Tap one of the objects and you'll be taken to its information page, where a simple set of symbols tells you whether you can see it with the naked eye, binoculars or a telescope.

A simple breadcrumb system along the bottom of the pages allows you to go back to either the search page or the map with a single tap. Tapping the telescope

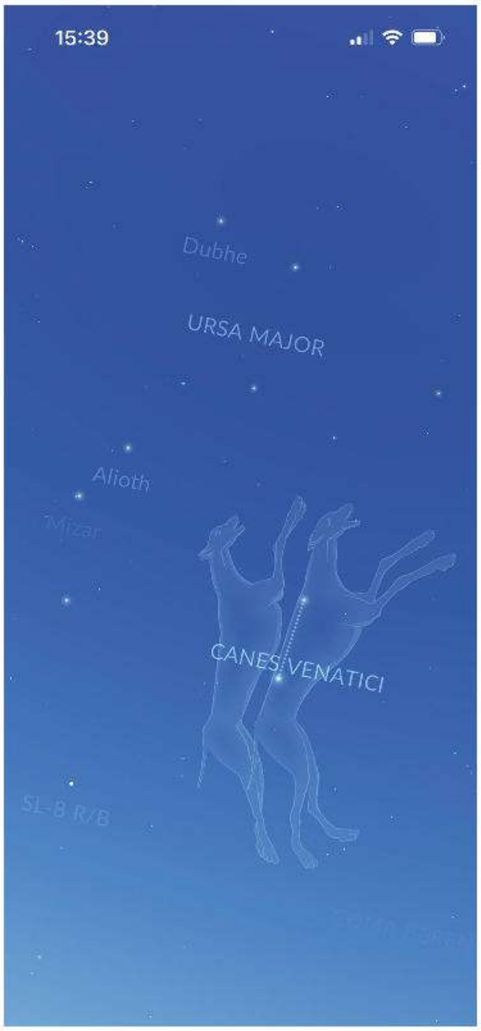
APP ADVICE

From: Vito Technology

Price: Free

From: App Store & Google Play

Operating system: iOS & Android



BEST FOR...

- SMALL BUDGETS
- BEGINNERS
- FAMILIES
- STARS & CONSTELLATIONS
- PLANETS
- MOON PHASES
- BRIGHT DEEP-SKY TARGETS

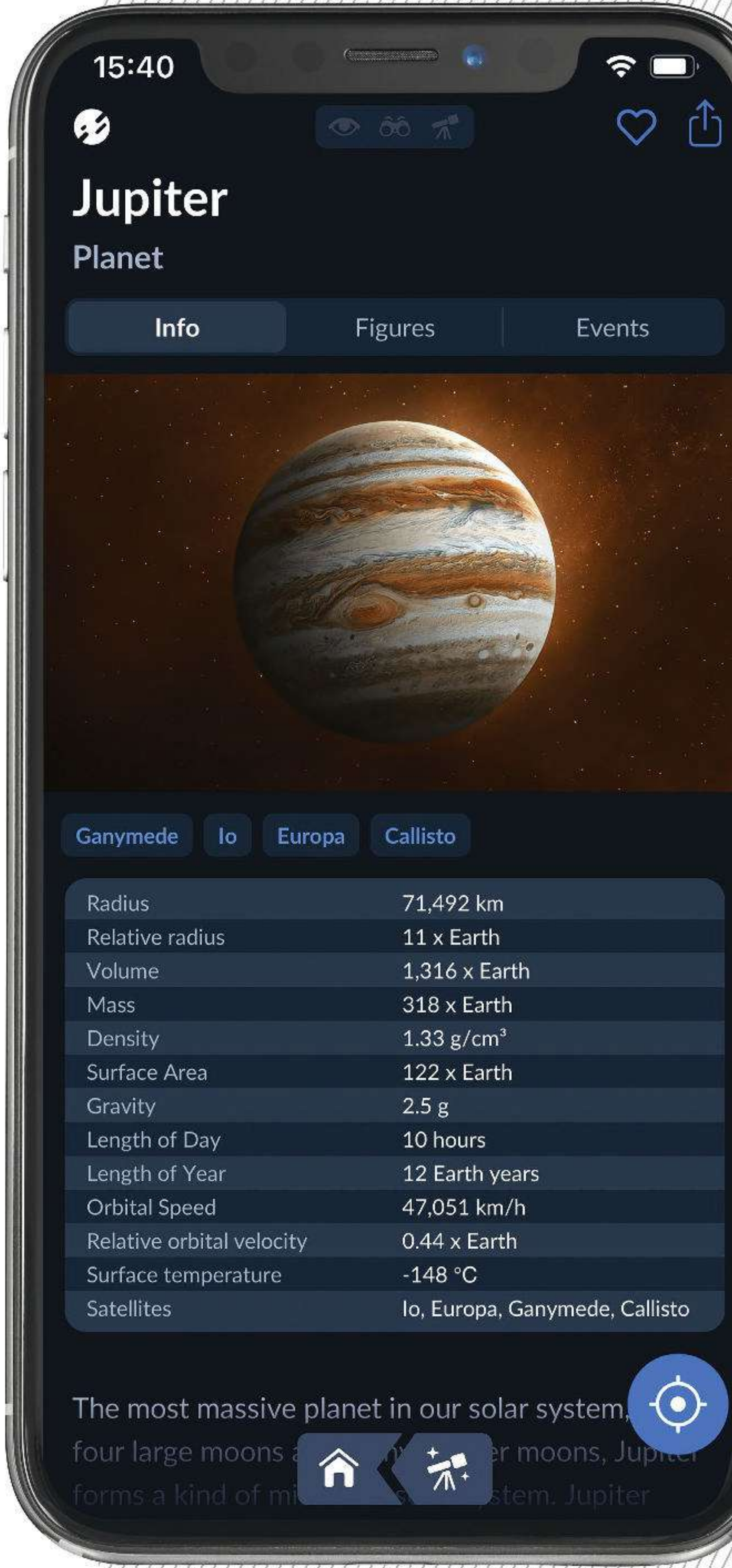
There's a wealth of information about targets available

Constellation depictions can be toggled on or off

icon from the home page brings up a list of what's visible from your location on a particular night – usually the day you're using it, though you can flip back and forth in the calendar. There's a stargazing index that puts together sunset time, Moon phase and likely cloud cover into a percentage score for how likely you are to see anything and a share button that condenses all the information into a single image you can post on social media or send through messaging apps.

The calendar button shows the same information, but split into days so you can scroll through looking for a clear night that's not too cold, while the three-line button opens a settings menu. The minimalist

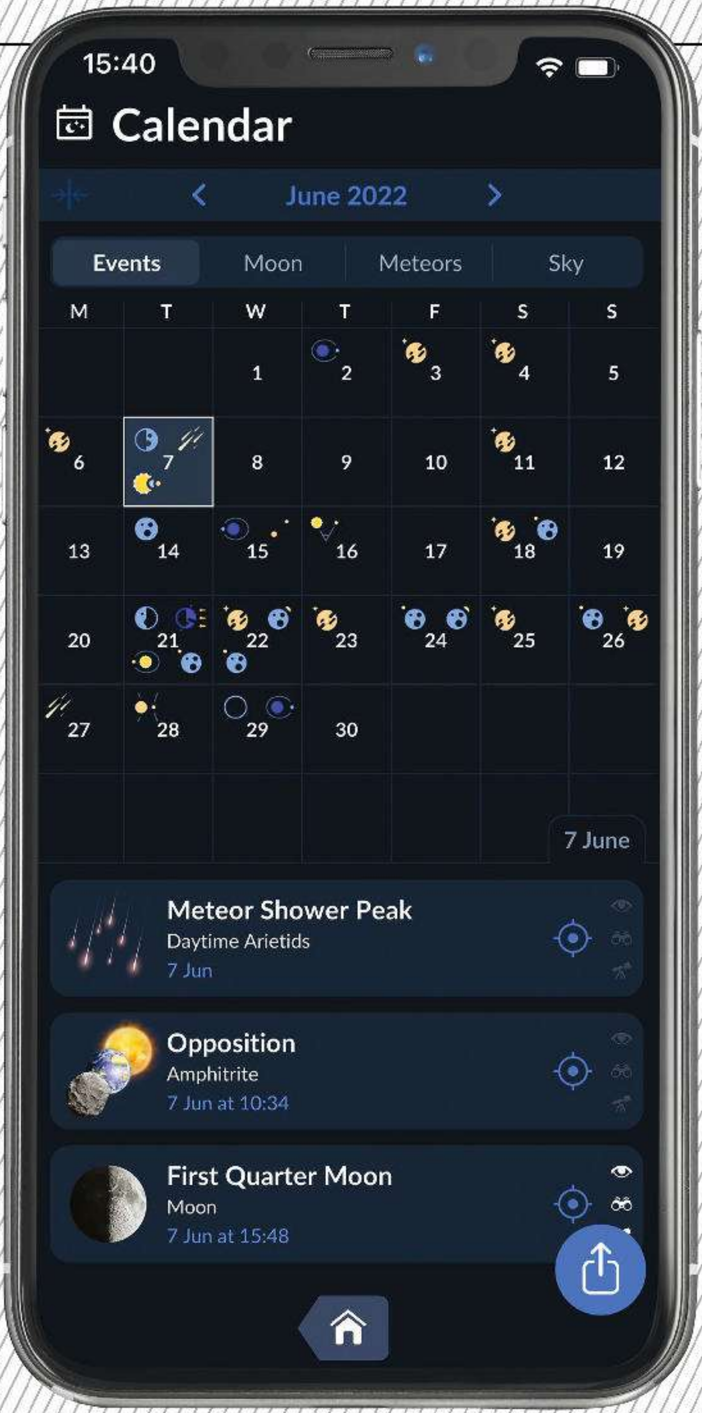
> "A simple set of symbols tells you whether you can see it with the naked eye, binoculars or a telescope"



Radius	71,492 km
Relative radius	11 x Earth
Volume	1,316 x Earth
Mass	318 x Earth
Density	1.33 g/cm³
Surface Area	122 x Earth
Gravity	2.5 g
Length of Day	10 hours
Length of Year	12 Earth years
Orbital Speed	47,051 km/h
Relative orbital velocity	0.44 x Earth
Surface temperature	-148 °C
Satellites	Io, Europa, Ganymede, Callisto

The most massive planet in our solar system,
four large moons a r moons, Jupiter
forms a kind of mi stem. Jupiter

> "Being able to look up the exact amount of cloud cover expected that evening is genuinely useful"


15:40

Calendar

June 2022

M	T	W	T	F	S	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

7 June

Meteor Shower Peak
Daytime Arietids
7 Jun

Opposition
Amphitrite
7 Jun at 10:34

First Quarter Moon
Moon
7 Jun at 15:48

The calendar section is great for planning ahead

FOR

- AR views of the sky
- Picks out the most interesting features

AGAINST

- Won't rotate into landscape
- Lacks information on individual stars

white-on-blue look of the app's map is very attractive, so it's a shame it will spend so much of its time in the ruddy tones of night mode. Still, better a red map than ruined night vision. The night mode itself is tucked away in the settings menu, requiring a couple of taps to find, disappointing for something that will be used so often.

Another niggle is that the app cannot be rotated into landscape. We do this all the time using Google Sky Map and other apps on our phones when using them to identify objects in the night sky, and having to use it in portrait takes a little getting used to. It does have the effect of making sure your fingers aren't obscuring the camera lens while using it in AR mode, however. Oddly, the developer accepts that holding your phone or tablet sideways has value, as it has added the ability to flip into landscape to the comparison table between Sky Tonight and Star Walk 2 on its website – Star Walk 2 can manage this feat.

The sheer simplicity of Sky Tonight works in its favour, however, whichever way you want to hold it. In our opinion, being able to aim it at the sky for a quick identification then getting it out later to read up on what you saw is the ideal way to use it. The information that accompanies many night-sky objects – the better known ones, at least – can be accessed from an 'i' icon from the map view or via search. The page is split into three, with an illustration and text description followed by 'figures' which show a real-time position and at which times the object will rise over the horizon and for how long. The final section, events, gives information about visible passes and anything else, such as occultations, that will occur in the next 30 days.

Tapping on a planet shows you its path through the sky, including the positions it will be at on certain dates. To fully appreciate this, it's best to zoom all the way out with two fingers, but unfortunately the app will not sustain this view, snapping back to its default zoom once you release the gesture. It doesn't do this if you zoom in.

Sky Tonight is free to download and use, but offers in-app purchases. A month of premium access, which switches off ads and removes the limitations of the free version – useful entries in the visible tonight and calendar screens are missing without a subscription – costs £0.99 or $0.99, while a lifetime subscription is £5.99 or $5.99. That's not bad value in terms of the information you get in one place, and we'd definitely choose the lifetime subscription over paying a month at a time – this is an app that will be useful all year round.

Sky Tonight tries to be the one app you need for stargazing. By bringing together so much information and displaying it so attractively, it achieves that goal more often than it fails at it. Not being able to rotate it into landscape is a niggle, but being able to look up the exact amount of cloud cover expected that evening is genuinely useful. With its nicely illustrated map of the constellations and the ability to use your device's camera to identify objects, you'll not be short of reading material when you head back inside to read up on the sights you've seen. There are several astronomy apps on the market, but few manage to present information with the style and depth that Sky Tonight manages.

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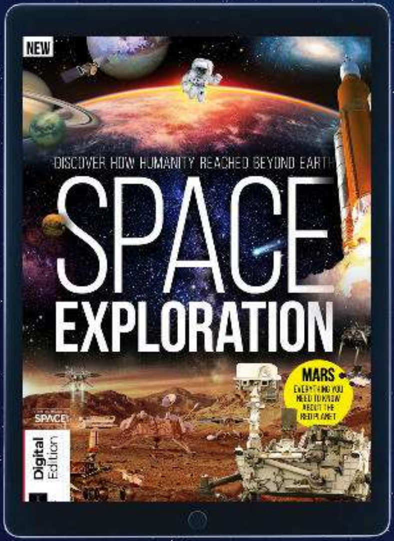
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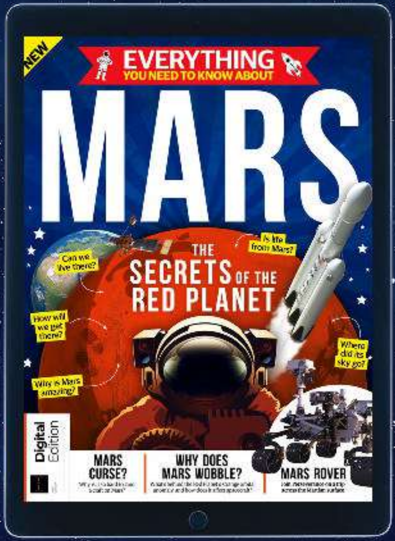
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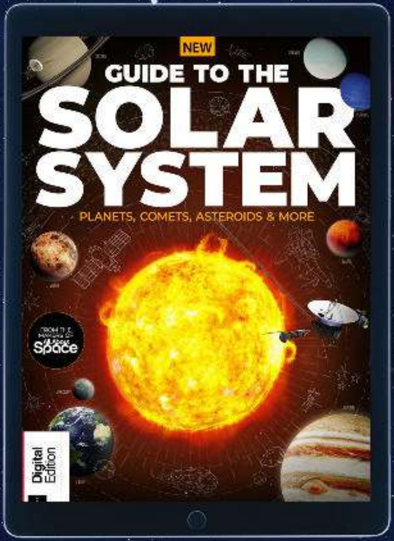
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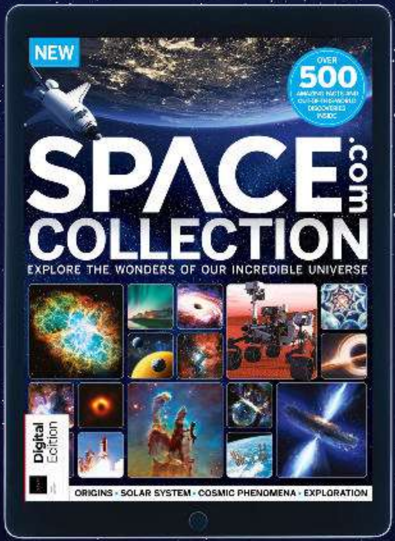
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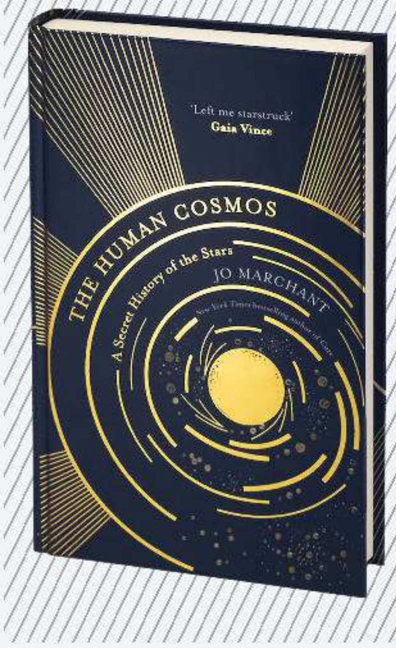
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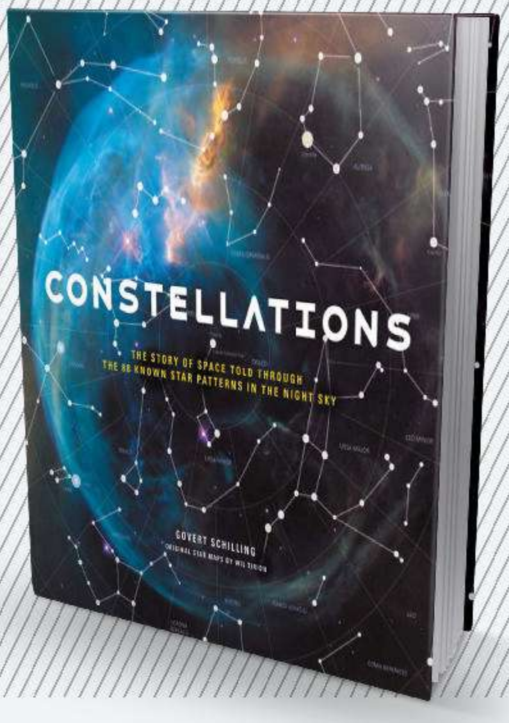
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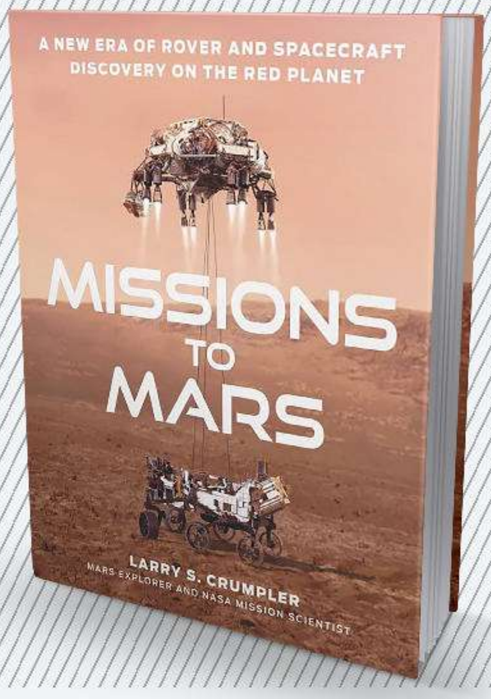
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MARS EXPLORER AND NASA MISSION SCIENTIST

The Human Cosmos: A Secret History of the Stars

Cost: £16.99 / $24.99
From: Canongate Books

1 Prepare for a cosmic view of our place in universal history with this enlightening volume where celestial cycles permeate our Earthly lives. Jo Marchant's book delves into our centuries-old relationship with the stars that shaped our personalities, religious beliefs, power structures, scientific advances and even our biology. Over the last few centuries we seem to have distanced ourselves from the universe that surrounds us, and that's the topic she focuses on here. Marchant guides readers on a tour through the history of humanity's relationship with the heavens and the cost of our separation from its influence. From the Hall of Bulls in Lascaux to a visit with Medieval monks grappling with the nature of time and native Tahitian sailors navigating by the stars, it's a re-examination of the potential of the universe we inhabit, its wonder and its effect on our health.

Constellations: The Story of Space Told Through the 88 Known Star Patterns in the Night Sky

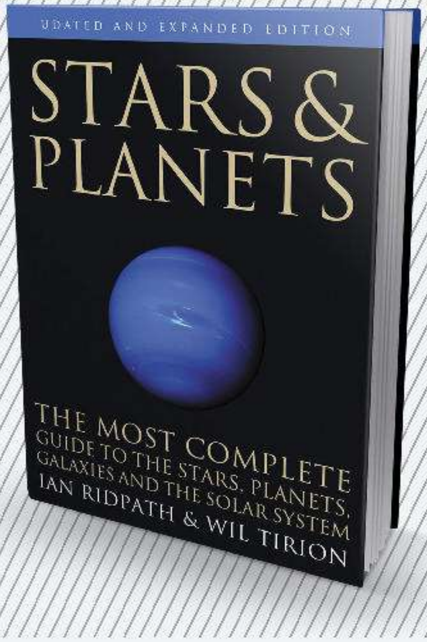
Cost: £25 / $29.99
From: Black Dog & Leventhal / Running Press

2 This lavishly adorned guide to all 88 constellations in the night sky, complete with an illustrated star map for each one by esteemed uranographer Wil Tirion, provides the exact location of every constellation, the details of its structure and data on its surrounding astronomical neighbours. Award-winning astronomy writer Govert Schilling takes us on this splendid visual tour, offering a complete history of astronomy via the lens of the constellations themselves. Organised alphabetically, his stargazing companion profiles each shining formation and includes basic information such as size, visibility and number of stars, as well as information on the discovery and official naming of the constellations and the myths and legends surrounding them.

Missions to Mars: A New Era of Rover and Spacecraft Discovery on the Red Planet

Cost: £25 / $35
From: HarperCollins

3 With all the recent attention paid to the Red Planet, it's nice to see a book detailing all the excursions humankind has made to our ruddy-coloured neighbour. This insider account of NASA's most important missions to Mars is injected with full-colour photographs and satellite imagery chronicling our voyage of discovery and the search for evidence of organic life on the planet. Author Larry Crumpler is one of the long-term planning leads for the Mars Exploration Rover project, where he assisted in the daily communications between NASA and the rovers crawling around the planet to collect scientific data. In this informative planetary biography, Crumpler recounts the history of the Red Planet from ancient times to pioneering discoveries being revealed by modern technology, including some of the first images from the Perseverance rover.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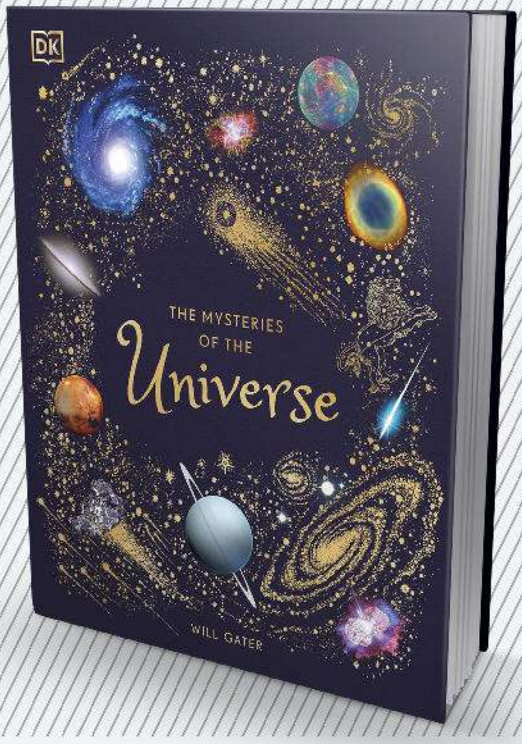

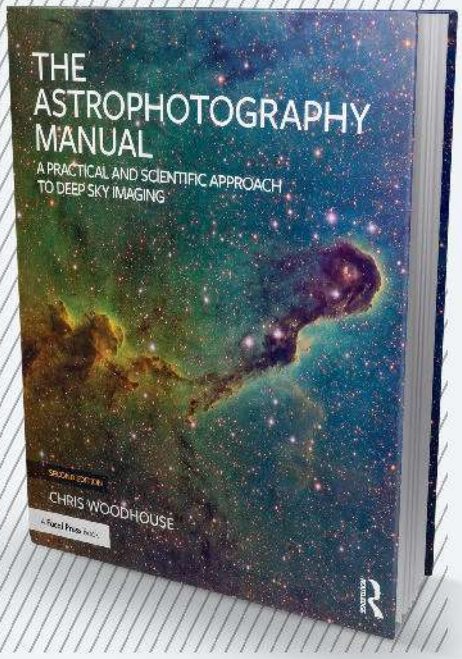
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CHRIS WOODHOUSE

Stars and Planets

Cost: £19.99 / $22.95
From: Princeton University Press

4 Here's an indispensable book to those of us who venture out in the early hours of the morning to catch a glimpse of a rising planet or shimmering star. In this updated and expanded edition of their classic compendium, Ian Ridpath and Wil Tirion offer stargazers and astronomers the most informative, comprehensive and authoritative celestial field guide available. It's the work of a 30-year collaboration between one of the world's leading astronomy experts and the planet's foremost celestial mapmaker and spotlights vivid colour sky charts, diagrams and photographs with clear writing, an attractive design and an easy-to-carry compact size. It includes the latest on stars, a revised chapter on recent research on exoplanets, revised charts, new photographs covering all 88 constellations in the Northern and Southern Hemispheres and detailed Moon maps. It even has top tips on choosing and using binoculars and telescopes.

The Mysteries of the Universe

Cost: £20 / $19.99
From: Dorling Kindersley

5 This beautifully illustrated and alluring volume is aimed at younger minds interested in astronomy and the universe. Within this guide's pages, children can encounter strange planets, distant stars and elaborate galaxies. From asteroids and comets to black holes, each page of this entertaining book reveals the secrets behind more than 100 celestial objects. Your little astronauts can embark on a journey out into the far reaches of the universe courtesy of storybook-style descriptions and simple text that delivers cool facts, myths and key discoveries in a fun way. Its 224 pages are arranged to present heavenly objects from the closest to Earth to those farthest away, all matched with colourful, out-of-this-world pictures. It's a book ideal for an educational astronomy-style bedtime.

The Astrophotography Manual

Cost: £49.99 / $66.95
From: Taylor & Francis

6 Drop down the celestial rabbit hole with this revised second edition of *The Astrophotography Manual*, perfect for photographers ready to leap beyond standard SLR cameras and editing software to craft indelible images of nebulae, galaxies, clusters and the stars. Author Chris Woodhouse starts with a brief astronomy primer, then marches readers on through the entire astrophotography process – from choosing equipment to capturing, calibrating and processing. Encompassing both technical and hand-on approaches, this edition also houses more than 170 pages of new content inside 22 new chapters, with 600 full-colour illustrations covering a wide range of hardware, including mobile devices, remote controls and new technologies. Also provided are useful insights into leading software, including Sequence Generator Pro and PixInsight.

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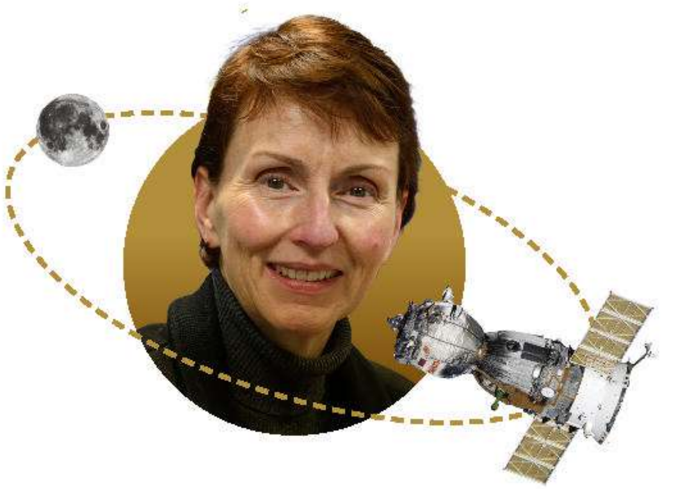

HELEN SHARMAN

Sheffield-born Sharman beat 13,000 other applicants to become Britain's first astronaut

18 May 1991 saw the first Briton blast off into space on the Soyuz TM-12 rocket. Helen Sharman pipped 13,000 other applicants to the post when she responded to a radio advertisement that asked for applicants to earn the title of first British astronaut aboard Project Juno – a cooperative arrangement between a group of British companies and the Soviet Union.

Sharman didn't grow up intending to be an astronaut. Born in Grenoside in Sheffield on 30 May 1963, she went on to gain a degree in chemistry at her hometown's university before moving to London to earn a PhD from Birkbeck, University of London. After her studies, Sharman found herself employed as an engineer before her passion for chocolate saw her working as a chemist for Mars Incorporated.

The British Project Juno space program consisted of the Soyuz TM-12 mission, which also had Sharman's fellow cosmonauts Anatoly Artsebarsky and Sergei Krikalev onboard. Leaving Earth for eight days, Sharman spent most of her time in space on board the Mir Space Station, becoming the first woman to visit the craft. Once on board the low-Earth orbit platform, for the most part the young astronaut was tasked with medical and agricultural tests. But it wasn't all carrying out experiments for Sharman – she also got the chance to take shots of the British Isles as the station orbited our planet and phoned home as she took part in an amateur radio hookup with British school children, who were in complete awe of her time in space.

Sadly, Sharman never returned to space. As her craft re-entered Earth's atmosphere, signalling the mission's end, this would be the first and only time she would have the privilege of experiencing such a venture. In 1998, she was one of three British candidates shortlisted for the 1992 European Space Agency astronaut selection process. Narrowly missing being selected, Sharman went on to follow a rewarding career as a broadcaster, a lecturer specialising in science education and joined the National Physical Laboratory as a group leader.

Despite her short time in space, Sharman's accomplishments have not been forgotten. She was appointed an OBE in 1993, and in the same year became an honorary fellow of the Royal Society of Chemistry. Being such an influential individual, Sharman has also had many schools in England, as well as the Netherlands, named in her honour.

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ON SALE
11 AUGUST

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ALL ABOUT SPACE

Future PLC Quay House, The Ambury, Bath, BA1 1UA

Editorial
Content Director **Gemma Lavender**
gemma.lavender@futurenet.com
Art Editor **Jonathan Wells**
Production Editor **Nikole Robinson**
Senior Art Editor **Duncan Crook**

Contributors
Stuart Atkinson, David Crookes, Robin Hague, Elizabeth Howell, Andrew Jones, Robert Lea, Richard Massey, Yuta Notsu, Jonathan O'Callaghan, Kai Rasmussen, Brent Robertson, Kulvinder Singh Chadha, George Spagna, Brandon Specktor, Alan Stern, Colin Stuart, Stefanie Waldek, Mike Wall, Mohamed Zaghoo

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Media packs are available on request
UK Commercial Director **Clare Dove**
clare.dove@futurenet.com
Advertising Manager **Matthew Johnson**
matthew.johnston@futurenet.com
07974 408 083
Account Manager **Garry Brookes**
garry.brookes@futurenet.com
0330 390 6637

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Content Director **Gemma Lavender**
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